CHAMBERS'S

INFORMATION FOR THE PEOPLE

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EDITED BY

WILLIAM AND ROBERT CHAMBERS

FIFTH EDITION

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PREFACE.

IT is now many years since CHAMBERS'S INFORMATION FOR THE PEOPLE first issued from the press. The cheapness of the work, its novelty, and the varied mass of useful knowledge which was embraced, rendered it a popular favourite. Without adventitious aid, its sale was immense. Since that time it has undergone numerous improvements both as regards matter and general appearance. Again, from the constant and rapid advance in every branch of science and art, it has been deemed necessary to recast the work in adaptation to the existing state of human knowledge. Hence the present, or FIFTH EDITION, which has been revised under the able Editorship of ANDREW FINDLATER, LL.D.

Designed in an especial manner for the People, though adapted for all classes, the work will be found to comprise those subjects on which information is of the most importance; such as the more interesting branches of science—physical, mathematical, and moral; natural history, political history, geography, and literature; together with a few miscellaneous papers, which seem to be called for by peculiar circumstances affecting the British people. Thus everything is given that is requisite for a *generally well informed man* in the less highly educated portions of society, and nothing omitted appertaining to intellectual cultivation, excepting subjects of professional or local interest. It will be understood, then, that the INFORMATION FOR THE PEOPLE is not an encyclopædia, in the comprehensive meaning of the word, but rather one embracing only the more important departments of general knowledge. The ruling object, indeed, has been to afford the means of *self-education*, and to introduce into the mind, thus liberated and expanded, a craving after still further advancement.

It may well be said of the present edition, as was said of the last, that the improvements are very considerable. The scientific treatises have, in general, been carefully remodelled, with due attention to recent discoveries. Subjects the interest of which is past have been omitted or greatly condensed, and others of a more enduring and important nature have taken their place. In the Indexes will be found a reference to almost every subject necessary in ordinary circumstances to be known.

In one important respect—that of the pictorial illustrations and embellishments—it must be obvious, to the most cursory observation, that a very great improvement has been effected.

W. & R. C.

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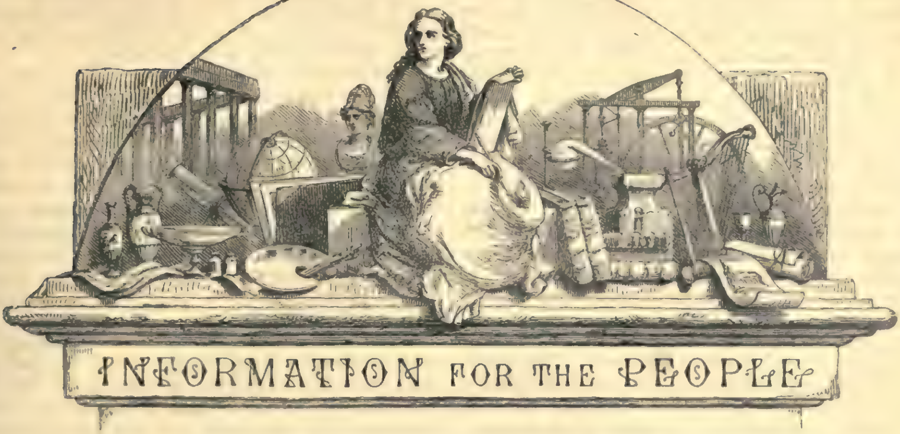


ASTRONOMY.

ASTRONOMY teaches whatever is known of the heavenly bodies. The earth itself it regards only as one of them—viewing it as an entire body, such as it would appear were we to behold it from a sufficient distance.

The subject falls naturally under two general heads: 1*st*, A *description* of the heavenly bodies—the aspect of the heavens as a whole; the distances, shapes, and magnitudes of the several bodies; the figures they describe in their motions; the way in which they are grouped into systems, &c. 2*d*, Physical Astronomy, or the nature of the powers or forces that carry on the heavenly motions, and the laws that they observe. The processes of calculating the motions from a knowledge of the laws, with a view to turn them to the use of man, and the management of mathematical instruments for taking the necessary observations, form the art of the practical astronomer; into which we cannot enter.

GENERAL APPEARANCES OF THE HEAVENS.

When we raise our view to the sky over our heads, we find it occupied with the sun by day, and the moon and stars by night. The sun is evidently never at rest, but is either ascending upwards in the sky from the east, or else sinking towards the horizon or sky-line in the west, where his body goes out of sight. The same continual motion of rising and setting is observed in the moon and in the stars. If, at the beginning of a winter-night, we fix our attention on a conspicuous star near the east point of the horizon, and continue to observe it, we shall see it rising higher and higher for about six hours; it will then begin to descend to the west, and in about six hours more it will reach the west point of the horizon, and disappear. If we commence our watch again on the following night, we may discover the same star rising at the east point at about the same hour, and going through its course of mounting, crossing, and descending the sky as before.

If we turn to some point between east and north, and notice a star just rising, we find it gradually ascending in the heavens up to a certain point; then descending to the west, and going out of sight; and finally reappearing in the east in about twenty-four hours from the time of its previous rising: but these twenty-four hours, instead of being spent one half above and the other half below the horizon, as in the former case, will be unequally divided between the presence and the absence of the star; more than twelve hours will be taken to pass from the rising to the setting, and less than twelve hours will elapse between the setting and the next rising. The further *north* the point of rising, the longer the time spent in the upper course, and the shorter the time in the under and unseen course. If we go to the north point itself, and observe a star just a little above the horizon, we shall find that it will spend the first twelve hours in ascending to its highest point in the heavens, and the next twelve in descending to the neighbourhood of the horizon; and it will not go beneath at all, but commence again to rise and describe a circle in the heavens as before; such a star, therefore, will be always in sight. In like manner, all stars in the north quarter lying within the circle described by this never-setting star will perform their daily movement above the horizon.*

Poles, Axis.—In the inside of these circling motions we may observe a point in the sky which

* In the foregoing and in succeeding paragraphs, it is supposed that the stars may be seen day and night. By the naked eye no star can be seen while the sun is up, but they are all in their places nevertheless. The intense light of the sun generally makes other celestial objects invisible. With good telescopes, however, the stars may be seen in the daytime, in a clear day, except in the sun's immediate neighbourhood. From the bottom of deep wells and mines the stars in the sky overhead are seen through the day. When the moon is at a considerable distance from the sun, it may be seen when the sun is up.

seems to be their common centre. A star lying in it would be perfectly at rest, and stars near it describe very small circles, or move within narrow limits. This point of rest is situated in the north quarter of the heavens, more than half-way up from the sky-line, towards the summit. It is called the *north celestial pole*, or the *north pole of the heavens*, and is the most important point in the sky for astronomical references. No visible star is actually residing in it; but a very bright star lies near it, called for that reason the *pole-star*.

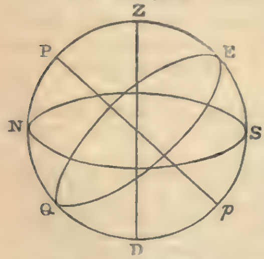
By observing the movements of stars that rise in the *south-east*, and seeing their visible paths becoming shorter and shorter, as they lie more southward, we cannot help inferring that there is a large region of stars describing circles wholly out of sight, and that there is a point beneath, which is the centre of these circles, corresponding to the centre of the northern heavens. This point is called the *south celestial pole*. An imaginary line drawn from pole to pole, or from the elevated north resting-point to the concealed south resting-point, is called the *axis of the heavens*, or the *axis of the world*. Owing to one pole being a considerable way up in the sky, and the other far down out of sight, it is evident that the great whirl of the starry sphere goes on in a *slanting* direction.

Besides the poles and axis of the heavens, there are many other imaginary points, lines, and circles, which it is convenient to suppose drawn among the stars, and which of course we can actually draw in all figures and sketches of the starry heavens. The most important of these may be here explained.

Equator, *Horizon*, *Zenith*, *Meridian*.—The celestial *equator*, so called because it cuts the starry sphere into two equal halves, is an imaginary circle passing round the heavens midway between the two poles. The two halves into which it divides the sphere of stars form the *northern and southern hemispheres*.

The *horizon*, or the line where the earth seems to meet the sky, makes another division of the starry sphere, into the visible hemisphere, or stars *above the horizon;* and the invisible, or stars *below the horizon*. The point of the heavens directly over our heads, or the very summit of our sky, is called the *zenith*. The point that we should see directly beneath our feet, if the earth could be seen through, is called the *nadir*.

Another artificial circle supposed to be drawn in the heavens, is the *meridian*. Like the equator and the horizon, it divides the starry sphere into two equal half-spheres, but in a different direction from either of those circles. In fact, it is so drawn as to be perpendicular to both. It passes through the north point of the horizon, then upward through the north celestial pole, through the zenith, down through the south point of the horizon, through the south celestial pole beneath, and finally through the nadir: so that, in the first place, it lies north and south; and in the second place, it stands upright. Thus, if in the figure, P*p* be the great axis of the heavens terminating in the north and south celestial poles, EQ the celestial equator, NS the horizon, and N and S the north and south points of it, Z the zenith, and D the nadir; then the enclosing circle of the figure NPZES*p*DQ is the meridian.



It is evident from this description, that when the sun or the moon passes the meridian, or lies due south, it has reached its greatest height, and will immediately commence to descend. Hence, also, we can determine the meridian line in the heavens, by observing where a star is when it ceases to ascend and begins to descend; which of course gives us the direction of the north and south points, and serves the same end as the mariner's compass. It is evident, also, that the middle point between a body's rising and setting is its meridian passage.

Fixed Stars and Wanderers.—Although the general starry sphere turns round in one great mass, so that each star is always in the same place among the other stars, it was early observed that there were exceptions to the common movement; and that a small number, besides going round the sky daily, shift about among the others. In opposition to these erratic or *wandering* bodies, the general multitude that kept their places were called *fixed stars*.

The moon, for example, is soon observed to be an erratic body. One night we see it near one star, and the next night it is at a considerable distance to the east of it; even in a few hours there is a visible change of position. In the course of a month, we find it has gone through a complete circle from west to east among the stars, and come back nearly to the same place.

The sun has a similar motion, though it is slower, and also less easily marked, because his light prevents the stars from being seen at the same time. If we could see a star any night setting at the same instant as the sun, we should find that the next night it would set four minutes *before* the sun, the sun having in the meantime moved backward a short distance.

Ecliptic, *Latitude*, *Longitude*, *Declination*, &c.—When this motion of the sun among the stars is observed for a length of time, it is found that it forms a circuit, bringing him back, in the course of a year, to the same position. The path, however, which he travels, is not exactly east and west, or parallel to the equator. If this were the case, the sun would rise and set always in the same points of the horizon. But we see that on the 21st of March, for instance, he rises exactly in the east; for the next three months the point of his rising is more and more north of east, till the 21st of June, when it begins to recede, and again reaches the east point on the 21st of September; and during the winter months it makes a similar approach to and retreat from the south. The amount of divergence either way is about a fourth of the distance between the east point and the north or south point. From this, and other appearances, it is evident that the annual path described by the sun among the stars runs slanting across the equator. This is an important circle in astronomy, and is called the *Ecliptic;* the angle which it makes with the equator is called its *obliquity*, and on this depends the variety of the seasons. Its amount is about a fourth of a quarter circle (23° 28′).

The points where the celestial equator and the

ecliptic cross one another are called the equinoctial points, because the sun is in them at the equinoxes. The vernal equinoctial point, called Aries, is used as a fixed mark from which to measure distances on the heavens east and west, just as we measure distances east and west on the earth, or terrestrial longitude, from Greenwich.

The terms *latitude* and *longitude* have different meanings in astronomy and in geography. The latitude of a place on the earth's surface is its distance north or south of the equator; the latitude of a planet or star is its distance from the ecliptic, while its distance from the celestial equator is called *declination*. The longitude of a place is its distance east or west from the first meridian counted along the earth's equator; longitude in the heavens is distance eastward from the point Aries, measured in the direction of the ecliptic, and not in that of the equator. The distance of a heavenly body from Aries, measured in the direction of the celestial equator, is called its *right ascension*. The reason why the ecliptic is chosen to refer the latitudes and longitudes of the heavenly bodies to, is, that it is the only circle in the heavens that approaches to the permanency of the earth's equator; it maintains almost a fixed position among the stars, while the celestial equator shifts its position in the course of ages, and thus divides the starry sphere differently at different periods.

Besides the sun and moon, there are a good many other wandering stars. The ancients discovered five of these, and gave them the name of *planets*, from the Greek word 'to wander.' The rest have been discovered since the invention of the telescope.

Copernican and Ptolemaic Systems.—We have hitherto spoken of the *appearances* of the heavenly bodies and their motions, without inquiring whether they are as they seem. These apparent motions were long considered to be real motions. The earth was believed to be—what it seems to be—a fixed station, the centre of the universe; the starry sphere was a solid shell, revolving daily with its thousand fixed fires round the central earth; while within it were a succession of crystal spheres, carrying the sun, moon, and planets, and, while partaking of the common motion from east to west, having also each a motion of its own. But as observations of the planetary motions were multiplied, it became more and more difficult to account for all the appearances in this way. At last it was found necessary altogether to change the point of view—to give up the earth as the centre of all the heavenly motions, and admit that it itself, along with the other planets, is in motion round the sun as a centre. This view, called the Copernican system, from Copernicus, its author, or rather reviver—for it had been held by more than one ancient philosopher—is now universally prevalent; the earlier is known as the Ptolemaic system, from Ptolemy, the chief ancient writer on the subject whose works we possess.

Instead of attempting to state the arguments by which the old opinions are refuted, we will proceed at once to give an outline of what is now believed to be the arrangement and constitution of the heavenly bodies. The simple way in which the Copernican system accounts for all the appearances, is the best argument in its favour.

THE SOLAR SYSTEM.

Of the heavenly bodies, those spoken of above as wanderers compose a group altogether apart, the earth being one of them. The sun, which is vastly greater than all the rest put together, forms the centre of the group; which is hence called the *solar* system (from *sol*, the Latin word for 'sun'). Though the distances of the bodies of this group, from the central sun and from one another, are enormous when measured by ordinary terrestrial standards, they become as nothing when compared with the space that separates the whole of them from the nearest of the fixed stars. The solar system forms thus a compact inner world, cut off by an almost immeasurable chasm from the outer universe. It is with this inner world that the astronomer has chiefly to do; what is known of the fixed stars will be spoken of apart, under the head of Sidereal Astronomy.

Around the sun as a centre, the smaller bodies or *planets* wheel at different distances in paths or *orbits* of a round form, being what are called ellipses; these orbits lie pretty nearly in the same plane, a plane passing through the sun's centre; and the motions of the planets are, as a general rule, all in one direction—from west to east.

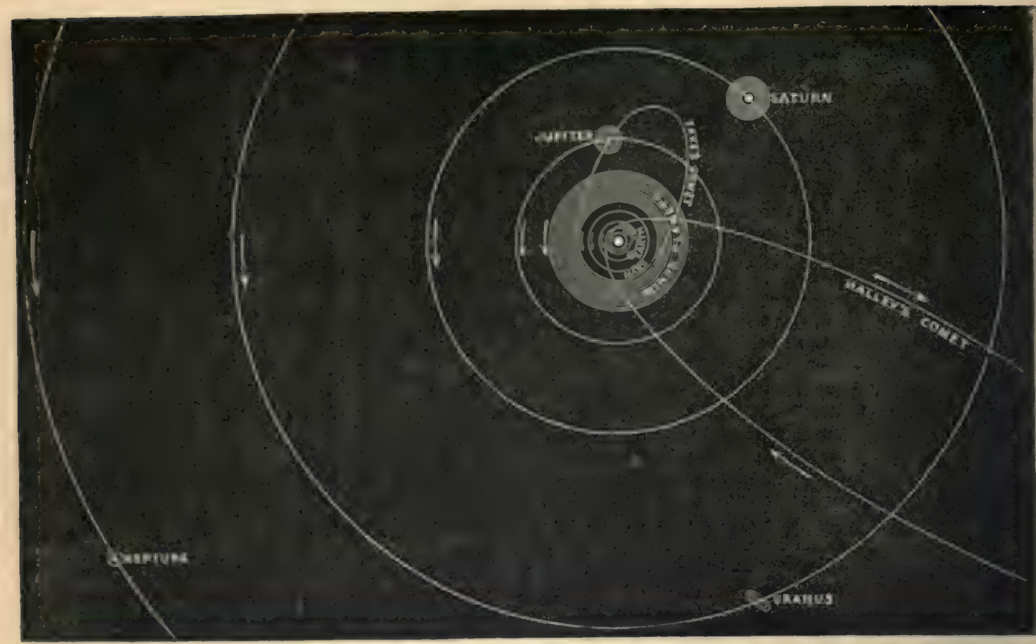
Some of the planets have other planets moving round them as centres—the moon, for instance, round the earth. These are called *secondary* planets, *moons*, or *satellites;* while those that move round the sun are called *primary* planets. The primary planets now known consist—*1st*, of eight larger planets, including the Earth; their names, in the order of their nearness to the sun, are—Mercury, Venus, the Earth, Mars, Jupiter, Saturn, Herschel or Uranus, and Neptune. *2d*, A group of small planets, called sometimes also asteroids, of which more than two hundred are now known. They are situated between Mars and Jupiter.

The satellites or moons, as yet discovered, number eighteen; of which the Earth has one, Mars two, Jupiter four, Saturn eight, Uranus four, and Neptune one. In addition to its moons, Saturn is attended by a luminous ring.

Those singular bodies called *comets* (Lat. *coma*, a lock or brush of hair) also belong, many of them at least, to the solar system. And in addition to the above luminous members of the system, it is now becoming apparent that there are multitudes of dark bodies, of various sizes, circling in the spaces between the known planets, some of which become visible to us when they accidentally enter our atmosphere as *shooting-stars* and other forms of *meteors*. See METEOROLOGY.

Such is a brief inventory, as it were, of the furniture of this inner world to which we belong. The figure on the following page represents the relative positions of the chief planetary orbits. Appended are tables of the diameters, distances, and other numerical particulars of the several bodies.

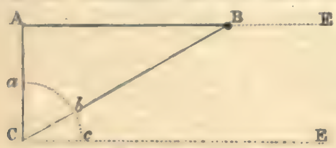
Astronomical Mensuration.—Though it would be inconsistent with the scope of the present sketch to describe minutely the processes by which these numbers are found, it is necessary to give a general idea of the methods followed, that the reader may be able to conceive the possibility of measuring and weighing objects so completely beyond our reach.



The Solar System, to the orbit of Neptune.

	Diameter in Miles.	Density, Earth's being = 1.	Mass, Sun's being = 1.	Distance from Sun in Millions of Miles.	Period of Revolution in Days.	Velocity in Orbit—Miles per Hour.	Velocity of Rotation at Equator—Miles per Hour.
MERCURY	2,962	1·24	$\frac{1}{4865751}$	35	88	105,330	386
VENUS	7,510	0·92	$\frac{1}{401211}$	66	225	77,050	1,010
EARTH	7,912	1·00	$\frac{1}{314760}$	$92\frac{1}{2}$	$365\frac{1}{4}$	65,533	1,040
MARS	4,920	0·52	$\frac{1}{2546247}$	139	687	53,090	628
MINOR PLANETS.							
JUPITER	88,390	0·22	$\frac{1}{1046}$	476	4,332	28,744	27,985
SATURN	71,904	0·12	$\frac{1}{3496}$	872	10,759	21,221	21,538
URANUS	33,024	0·18	$\frac{1}{24899}$	1754	30,687	14,963	10,921
NEPTUNE	36,620	0·17	$\frac{1}{18780}$	2746	60,127	11,958	?
SUN	852,584	0·25	1	*	*	*	4,407
MOON	2,153	0·63	$\frac{1}{24490744}$	*	*	2,273	10

The astronomer finds the distance between objects, not by measuring lines, but by measuring *angles*. Even distances on the earth are most

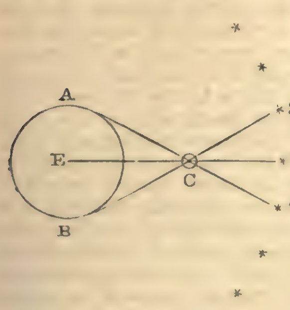


accurately measured in this way, as in trigonometrical surveying. Suppose that an observer at A wishes to ascertain the distance of an inaccessible object at B; it could never be found by looking at it from A alone. He chooses another station, C, to which he has access, in a direction perpendicular, we shall say, to the direction of B, and at a convenient distance, say 100 yards. If the object looked at from A lay directly east, it will no longer be east when looked at from C; its direction is now CB, not CE, and the difference of direction is seen in the greater or less wideness of the opening between those two lines, or in the *angle* BCE, as it is called. The size of such an angle is ascertained by describing a circle from the point C, and measuring how many degrees (that is, 360th parts of the circle) the arc *bc* contains.

By considering the figure, it will be seen that the more distant B is, the smaller must be the angle BCE, and also ABC, which is evidently equal to BCE. For every size of the angle ABC, there is a certain fixed length of AB (the length of AC remaining the same); and trigonometry teaches, from knowing the *base* AC and the angle opposite, to find the length of AB. Everything depends on measuring the angles of direction, or the angular distances, accurately. Degrees are divided each into 60 parts, called *minutes*, and these again into 60 parts, called *seconds*; and astronomical instruments are now so delicate that a difference of direction of one second can be measured.

The difference of direction in which a body is seen when viewed from two places at a distance from one another, is called by astronomers

parallax, or displacement. The annexed figure represents the effect of parallax on a heavenly body C. V is its *true* place, or place in the sky as seen from the earth's centre; T is its place as seen from the surface at A, and the arc TV, or the angle ACE, is the amount of the horizontal parallax.



The distances of the heavenly bodies, even the nearest of them, are so great, that even when the two stations are taken as wide apart as possible—that is, from the opposite sides of the earth, where the distance between them is equal to the earth's diameter, or nearly 8000 miles—the angle of parallax ACB, or the displacement on the sky TS, is very small. In the case of the moon, the nearest of the heavenly bodies, it is nearly two degrees; and by means of it the distance of the moon is found to be about 239,000 miles, or about sixty times the half-diameter or radius of the earth. When the sun is observed from opposite sides of the earth, he suffers a displacement of only seventeen seconds of a degree. On so small an angle, a slight error of observation materially affects the result; and therefore other expedients were had recourse to, to determine the sun's distance with greater certainty and exactness, which may be stated in round numbers as 92,500,000 miles. When the distance of the earth from the sun was once known, a new and vastly extended base was obtained for the trigonometrical survey of the heavens. As the earth travels in its annual circuit round the sun at the distance of 92,500,000 miles, by observing a heavenly body at two different times, at an interval of six months, we in effect observe it from two stations removed from each other by the whole breadth of the earth's orbit, or nearly 185,000,000 miles. The displacement produced in this way is called *annual parallax*. Even this enormous base becomes as nothing when applied to measure the distances of the fixed stars; by far the greater number shewing no sensible parallax.

Knowing the distances, we can find the real sizes of bodies from their apparent size, or from their dimensions, taken by an angular instrument. If an object be a mile off, and if its breadth make an angle of 1° at that distance, its lineal breadth is determined by these two quantities. Thus the *moon*, being about 239,000 miles from the earth, and having an angular breadth in the sky of somewhat more than half a degree, its actual breadth must be about 2000 miles. The accurate estimate is 2153 miles. The *sun* has almost the same apparent size in the sky as the moon; but being at nearly 400 times the distance of the moon, it must have nearly 400 times the breadth of the moon to appear equally large. The diameters of the planets are determined in the same way.

The solid contents or *volumes* of the several bodies are found from their diameters, by a simple rule of geometry. To state the number of cubic miles that each contains, gives little real information, the important thing being their relative magnitudes. Now, it is important to bear in mind that the magnitudes or bulks are not in the simple proportion of the diameters, but as the *cubes* of the diameters. Thus, the diameter of the sun being about 107 times that of the earth, his volume or bulk will be 1,200,000 (107 cubed) times greater.

To speak of *weighing* such stupendous masses as the sun, moon, and stars, seems at first sight extravagant; yet it is by no means one of the most difficult problems, as will be explained under Physical Astronomy.

Diameter of the Earth.—In measuring the distances of the heavenly bodies, the diameter of the earth is taken as a known base to start from; but how is this got at? If at any place we observe the height of a star on the meridian—say the pole-star—and after travelling directly north for a considerable distance, observe the height of the same star, it will be found to be greater. This arises from the round form of the earth; and it is easily shewn that, if the star has risen one degree higher in the heavens, the observer must have moved north one degree. We are thus enabled to fix two stations on a meridian, the distance between which shall be exactly one degree, or the $\frac{1}{360}$th part of the whole circle or circumference of the earth. When the length of such a line is measured, it is found to be a little less than seventy English miles. This, multiplied by 360, gives the whole circumference in round numbers at 25,000 miles, and the diameter at 8000.

SEPARATE MEMBERS OF THE SYSTEM.

The Sun (☉).—The apparent or angular breadth of the sun, at the mean distance of the earth, is slightly more than 32′. The real diameter of the sun is 853,380 miles, which, as already stated, is 107 times that of the earth, so that in volume or bulk the sun is equal to 1,200,000 earths.

That the sun is a ball or globe is evident from its always appearing round, while we know, at the same time, that it turns or rotates on an axis. The fact of its rotation, and the time it occupies, are inferred from observing the motion of the dark *spots* which are seen at times on its surface: the period of rotation is ascertained to be a little over 25 days.

A solar spot presents the appearance of a black irregular patch, called the *umbra*, surrounded by a less dark fringe, called the *penumbra*. Spots appear and disappear very irregularly, some lasting only a day, others for weeks and even months. Sometimes few or no spots are to be seen, at other times they appear in profusion; and these alternations are observed to come regularly round in periods of about *ten years*. Individual spots have been seen to attain the enormous breadth of 50,000 miles, covering an area of five times the surface of the earth. They are inferred, with almost certainty, to be hollows.

Around the spots, and on other places, there are often masses brighter than the general surface, which are called *faculæ*, or torches. The general surface itself is not uniform, but appears to be coarsely mottled, and to be made up of bright roundish patches, with soft edges, sprinkled irregularly on a less luminous background. The move-

ments and changes, of almost incredible velocity and magnitude, constantly going on in the spots and bright patches lead irresistibly to the conclusion that the luminous surface of the sun—his *photosphere*, as it is termed—is of a cloudy nature.

But during a total eclipse of the sun, when his shining disk is covered by the dark body of the moon, there is readily seen a white halo, called the *corona*, surrounding the moon; within this there were first observed fantastically shaped masses of a red colour, projecting considerably here and there beyond the moon's edge, and variously called red flames and red prominences; and closer observation has shewn that these larger prominences are connected by a continuous belt of similar colour at a lower level. This less brilliant envelope is known as the *chromosphere*.

By bringing that new and marvellous instrument of investigation, the *spectroscope*, to bear on those appearances, a good many points have of late been established regarding the physical constitution of the sun—that is, what substances it is composed of, and the condition in which those substances exist. To explain the action of the spectroscope belongs to Optics; it is sufficient here to say, that it tells whether a distant luminous body is in a solid or liquid state, or whether it is in the state of vapour; and can discriminate between the light proceeding from incandescent hydrogen, for instance, and that from the vapour of sodium or of iron. The chief results arrived at may be thus summed up: The sun is composed of substances identical, in part at least, with those composing our earth; hydrogen, sodium, iron, magnesium, and several other metals have already been fairly ascertained. The matter of the sun is so intensely hot as to be to a great extent in the state of vapour; at all events, it is so to a considerable depth at the surface. The outer envelope, or cromosphere of the sun, consists mainly of hydrogen. Below this, we have the photosphere, or region containing metallic vapours, along, probably, with numerous deposited cloud-particles of these vapours, which particles are the chief source of the light and heat of the sun. The photosphere is in a state of constant agitation, like that of boiling, caused, apparently, by the portions on the surface cooling by radiation and rushing down at one place, while hotter matter from the interior is heaved up at another. When these 'convection-currents' are exceptionally violent, they become visible as faculæ and spots, the blackness of the latter being caused by a great down-rush of the comparatively cold matter from above into a hollow of the photosphere. This agitation of the photosphere causes a corresponding commotion in the chromosphere; where the photosphere is upheaved, masses of the red-hot hydrogen envelope are projected far above the general level, sometimes to the height of tens of thousands of miles, and form prominences. The velocity of these uprushes, and still more of the whirling motions going on in the hydrogen, is astonishing, being sometimes not less than 120 miles a second. The nature of the *corona* is yet not fully ascertained.

As to the sun's *heat*, it has been calculated that the amount given out by one yard of his surface is as great as that which would be produced by burning six tons of coals on it each hour. The amount received by the earth in one year would be sufficient to melt a layer of ice 100 feet thick all over the earth's surface. But the sun's heat is given out equally all round, so that the portion intercepted by the earth at its distance of 92,500,000 miles must be an inconceivably small fraction of the whole that is lost by the sun.

Is the sun becoming cooler with all this loss? It must be so, unless the loss is in some way made up. The most probable theory of the origin of the existing store of solar heat is, that the matter composing the sun was originally diffused in a nebulous form throughout space, and that this matter, falling together by gravity, had its motion converted into heat, just as two stones are heated by clashing together. But we know of no source from which the continual dissipation is replenished; and without fresh fuel, the fire, however big, must in the end go out. 'There will come a time when the sun, with all its planets welded into one mass, will roll, a cold black ball, through infinite space.'—*Lockyer's Astronomy.*

Mercury (☿) and *Venus* (♀), the two members of the system next to the central body, are called *inferior* planets, from their orbits being within that of the earth. Owing to their position, they can never appear at any great distance or *elongation* from the sun. Mercury, in fact, even at its greatest elongation, sets long before the end of twilight, or if west of the sun, does not rise till the dawn has begun; so that in our latitude and cloudy climate, it is rarely seen with the naked eye. Venus attains more than twice the elongation of Mercury, and is seen long after night has fairly set in, or before the morning twilight. Both inferior planets go through *phases* like the moon, and when seen through a telescope, have a crescent or a gibbous shape. They are never seen when full, or when new, being then near the sun. Venus is the most conspicuous of the heavenly bodies, next to the sun and moon; when it rises before the sun, it is called the *Morning Star*—the Lucifer of the ancients; and when it sets after the sun, it is the *Evening Star* or Hesperus.

Telescopic observations of Mercury and Venus are very difficult, owing to the intense brilliancy of the surface; hence nothing has been ascertained as to their physical constitution. Even the times of their rotation on their axes cannot be held as accurately determined.

The *Earth* (⊕) is the third planet in order from the sun, and closely resembles Venus. The earth is not a perfect sphere; it does not measure the same in all directions, but has its axis, or the diameter on which it rotates, shorter than its diameter at the equator. This is a general law in all planets, the cause of which will be explained afterwards. The earth, then, is flattened at the poles, and its shape is called by astronomers an oblate spheroid. If it were cut in two, by a plane passing through the two poles, the section would be, not a circle, but an oval, or *ellipse;* and the excess of the *equatorial* diameter over the *polar* diameter is called the *ellipticity* of the spheroid. The ellipticity of the earth is found to be $\frac{1}{300}$, or the equatorial diameter exceeds the polar by $\frac{1}{300}$th of its length. This was determined in two ways: by measuring degrees of the meridian at different latitudes; and by measuring the variation in the force of gravity, between the equator and the poles. The polar diameter, omitting fractions, is 7899 miles, the equatorial 7925;

the difference is thus 26 miles, and the mean diameter 7912 miles.

To ascertain the density of the earth, is a delicate problem, to be more particularly described under the head of Mechanical Astronomy. It is found to be from $5\frac{1}{2}$ to 6 times that of water. The densities of the other heavenly bodies are always given as compared with that of the earth, which is stated as 1. The motions of the earth, and the appearances caused by them, as well as the motions of its accompanying satellite, the moon, will be described under separate heads (see also PHYSICAL GEOGRAPHY).

Mars (♂), the fourth in order, is the nearest to us of the *superior* planets. In many respects it resembles our earth. It is distinctly ascertained to turn on its axis in 24 hours 37 minutes, the axis being inclined to the plane of its orbit at an angle of 28° 27′. Its days, then, are nearly the same as ours; and its year, which contains 668 Martial days, is varied by seasons like the terrestrial year. Mars has a reddish aspect. Around each pole is a region of dazzling white, conjectured to be snow. In 1877 it was discovered to be attended by two satellites.

The *asteroids* or *small planets* circulate in a region lying between the orbits of Mars and Jupiter, but on the whole nearer to the former. They form a distinct group of themselves. It is only recently that the existence of the small planets has become known, the first, Ceres, having been discovered in 1801. From observing, however, that the distances at which the planets generally succeed one another, form a kind of progression, that of each orbit, counting from Mercury, being nearly double of the one preceding, it had long been conjectured that a planet or planets might yet be discovered in the interval between Mars and Jupiter, which formed a break, as it were, in the regularity of the progression. The discovery of Ceres by Piazzi at Palermo in Sicily (Jan. 1, 1801), was speedily followed by that of Pallas, Vesta, and Juno; and up to the present time more than 200 have been catalogued and named.

In addition to their comparative smallness, the planets of this group are distinguished by their orbits being much more elliptical or elongated than those of the others, and also having a greater inclination—that is, rising and sinking much farther from the plane of the ecliptic. The inclination of Pallas is as much as 34° 37′. The diameter of the largest of the minor planets is only 228 miles, and many of the smaller ones are less than 50. They are invisible to the naked eye, except occasionally Ceres and Vesta.

From various observed facts, cosmogonists presume that the matter which in other cases has gone to form one planet of the first rank, has in their case been separated into several parts, assuming various but connected orbits.

Jupiter (♃).—The largest of all the planets is Jupiter. The diameter of Jupiter being upwards of eleven times that of the earth, his volume is 1400 times the volume of the earth. To the inhabitants of Jupiter the sun must appear less than one-fifth of the breadth he presents to us. By means of permanent marks, it is ascertained that the planet rotates on an axis inclined to its orbit at the small angle of 3° 4′, and in the short space of 9 hours 55 minutes. This makes the rotary velocity of Jupiter's surface twenty-seven times greater than that of the earth. Viewed through a telescope, Jupiter appears traversed by dusky streaks parallel to the planet's equator. Both Jupiter and Saturn have atmospheres so densely laden with clouds that the surfaces of the planets are, it is believed, never seen; and the parallel streaks, which both exhibit, are supposed to arise from the rapid rotation of those planets disposing the clouds in belts, on the principle of our trade-winds and calm-belts. The density of Jupiter, taking his bulk as we see it, is little more than that of water; but if he is surrounded by a thick envelope of cloudy atmosphere, the kernel of the planet may approach that of the earth. The same may be said of Saturn, whose density as a whole is about half that of water.

Jupiter is attended by four satellites, which revolve round it as the moon revolves round the earth, but in much shorter periods—the nearest requiring only forty-two hours. One of these satellites is of the same size as our moon; the others, larger. Their density is very small; so that the mass of the whole is only a 6000th part of that of Jupiter itself. The satellites of Jupiter were discovered by Galileo, being among the first results of the invention of the telescope.

Saturn (♄) with its ring, or rather rings, and eight moons, is the most remarkable member of the solar system. It turns on its axis in 10 hours 29 minutes.

The ring of Saturn, which surrounds the planet in the plane of its equator, is found, on closer examination, to consist of a series of rings one within the other, the two outer being bright, and the innermost dark and transparent. The distance from the body of the planet to the dark ring is 9760 miles. The whole ring system, inclusive of the interval between the two bright rings, is 37,570 miles broad, while its thickness appears not to exceed 100 miles. In certain positions of the planet, we can see its surface at a considerable angle, and the openings or loops which it forms at the sides of the planet. At other times, we see its dark side, or only its edge. It is now generally believed that these rings are composed of innumerable small satellites, moving each in its own orbit round the planet, and presenting a bright appearance where they are densely packed, but a dim appearance when scattered.

The eight satellites of Saturn revolve around it, on the exterior of the ring, and almost all of them in nearly the same plane. They are so small as not to be visible without a powerful telescope.

Uranus (♅) is invisible to the naked eye, and was discovered by Sir William Herschel in 1781. Owing to its enormous distance, little is known regarding it.

Uranus is attended by at least four satellites. In two respects, these satellites are quite singular: their orbits are nearly perpendicular to the plane of the ecliptic; and their motions in the orbits are *retrograde*—that is, from east to west, instead of being from west to east, like those of all other planets both primary and secondary.

The discovery of *Neptune* (♆) is one of the greatest triumphs of scientific astronomy. From irregularities observed in the motion of the planet Uranus, it had been conjectured that some disturbing cause, not yet discovered, was acting upon

it. Two astronomers, M. Le Verrier, in Paris, and Mr J. C. Adams of Cambridge, independently of one another, calculated where this disturbing cause must be situated. The results of Le Verrier were first made public; and Dr Galle of Berlin detected the new planet at the first search, September 23, 1846, within two diameters of the moon's disk from the place assigned for it by both astronomers.

UNIFORMITIES OR LAWS IN THE SOLAR SYSTEM.

These details of the movements, magnitudes, distances, &c. of the separate members of the solar system, are apt at first sight to appear a mass of unconnected facts, without any discernible plan; but more attentively considered, they display in several respects order and law.

The first important uniformity to be noticed among the planets is, that their orbits lie all nearly in one plane. If we take the plane of the earth's orbit, which is the same as that of the ecliptic, as a standard of reference, and suppose it represented by a ring held horizontally with the sun in its centre, then the other orbits will be represented by other rings, two within, and the others without, held so as also to have the sun in the centre, and (with the exception of a few of the planetoids) never rising above or sinking below the level of the earth's ring more than a very few degrees. In consequence of this arrangement, the motions of the planets, as seen from the earth, are confined to a narrow zone of the heavens, extending 9° on each side of the ecliptic. This circular belt, called the *Zodiac*, was from the earliest times divided into twelve equal parts, called *signs*, containing, of course, 30° each. These signs received each a particular name, from the groups of stars or constellations in them having a fancied resemblance to certain figures, chiefly of animals. The names of the signs, with the symbols by which they are usually represented, are as follows:

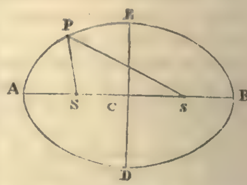
♈ Aries, the Ram.	♎ Libra, the Balance.
♉ Taurus, the Bull.	♏ Scorpio, the Scorpion.
♊ Gemini, the Twins.	♐ Sagittarius, the Archer.
♋ Cancer, the Crab.	♑ Capricornus, the Goat.
♌ Leo, the Lion.	♒ Aquarius, the Water-bearer.
♍ Virgo, the Virgin.	♓ Pisces, the Fishes.

This division of the zodiac affords a ready means of pointing out the place of a planet, or of the sun or moon, at any particular time, by telling in what sign it is.

Besides moving nearly in one plane, the planets move all in one direction—namely, from west to east. The same law prevails among the satellites, with the remarkable exception of those of Uranus, which have a *retrograde* movement, or from east to west.

But the grand uniformities of the solar system are those discovered by the celebrated astronomer Kepler, and known as 'Kepler's Laws.' Kepler merely deduced them as matters of fact from the observations of himself and others; it remained for Newton to discover their cause. One of these laws respects the exact form of the paths in which the planets move. The ancients, from some imaginary perfection which they attributed to the circle, had taken it for granted that all celestial movements must be circular; Kepler made the important discovery that this is an error, and that the planetary orbits are *ellipses*.

The ellipse is an important figure in astronomy; for not only are the planetary orbits ellipses, but the planets themselves have an elliptical shape, as we saw when speaking of the form of the earth. There is a ready practical way of describing an ellipse, which at the same time gives a good sensible notion of its nature. If the ends of a thread are fastened by pins to two points S and *s*, at a distance apart less than the length of the thread, and if the point of a pencil P, is put into the loop of the thread, and moved round so as to keep it stretched, the pencil will trace an ellipse.



The two points S and *s* are called the *foci* of the ellipse; AB is the major or transverse axis, C the centre; and SC, the distance of the focus from the centre, is the *eccentricity*. With the same length of thread, a variety of ellipses may be described, by altering the distance between the points S and *s*. The nearer they are brought to each other, the rounder does the figure become; and when they come together, it forms a perfect circle. In the planetary orbits, the sun is always in the focus S, and therefore the planet is at different distances from the sun in different parts of its orbit. When it is at A, the nearest point, it is said to be in *perihelion;* and when at B, in *aphelion.* SE is the mean distance, and is equal to AC. The planetary orbits differ very little from circles, or have very little eccentricity.

Another of Kepler's laws connects the change of a planet's distance from the sun with the speed of its motion: when the distance *increases*, the speed *diminishes;* and at the least distance we find the greatest speed. The exact nature of the relation is expressed by saying that the areas swept over by the line joining the sun and planet, which line is called the *Radius Vector*, are equal in equal times. This is known as the law of *Equal Areas.*

The two laws already noticed refer to the motions of a single planet; the third law shews a relation between the motions of all the planets, or all the bodies that revolve round the same centre. It is, that *the squares of the periodic times of any two planets are to each other as the cubes of their mean distances from the sun;* that is, if there be two planets, and one farther off than the other, the near planet will perform its revolution quicker than the other, in the proportion above expressed. The same three laws apply to the revolutions of satellites about their primaries.

DIURNAL AND ANNUAL MOTIONS OF THE EARTH.

The earth, like all the other planets, has two motions: it whirls round its axis once a day; and while doing so, it is all the while travelling bodily through space in a wide circuit round the sun, which it accomplishes in a year. The first is called a motion of *rotation*, the second of *translation.* The two combined give rise to the vicissitudes of day and night, and of the seasons.

The circumference of the earth being 25,000 miles, any spot at the equator, in order to go round in twenty-four hours, must move upwards of 1000 miles an hour. This velocity decreases

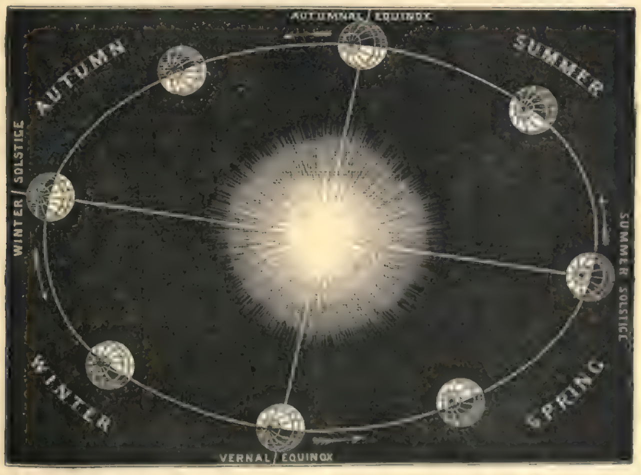
towards the poles, because the circles to be described become less; but in Great Britain it is still nearly 600 miles an hour. We are not sensible of this motion, because we and all our surroundings are carried along with it. It is in this way that the swift, but smooth and noiseless whirl which carries the earth's surface and its inhabitants eastward, makes the starry vault seem to flit past the eyes of these inhabitants towards the west.

It is the earth's rotation that causes the vicissitude of day and night. The earth being a globe, only one-half of it can be in the sun's light at once; to that half it is day, while the other half is in its own shadow, or in night. But by the earth's rotation, the several portions of the surface have each their turn of light and of darkness.

Length of a Day.—One complete rotation of the earth does not make a day, in the usual sense. If the time is noted when a particular fixed star is exactly south or on the meridian, when the same star comes again to the meridian the next day, the earth has made exactly one rotation, and the time that has elapsed is called a *sidereal day*. This portion of time is always of the same length. Sidereal time, or star-time, from its unvarying uniformity, is much used by astronomers. But the passage of a star across the meridian is not a conspicuous enough event for regulating the movements of men in general. It is not a complete rotation of the earth, but a complete alternation of light and darkness that constitutes their day. This, which is called the *natural* or the *solar* day, is measured between two meridian passages of the sun, and is about four minutes longer than the sidereal day. The cause of the greater length is this: When the earth has made one complete turn, so as to bring the meridian of the place to the same position among the fixed stars as when it was noon the day before, the sun has in the meantime moved eastward nearly one degree among the stars, and it takes the earth about four minutes more to move round so as to overtake him. If this eastward motion of the sun were uniform, the length of the solar day would be as simple and as easily determined as that of the sidereal. But the ecliptic or sun's path crosses the earth's equator, and is therefore more oblique to the direction of the earth's rotation at one time than another; and besides, as the earth moves in her orbit with varying speed, the rate of the sun's apparent motion in the ecliptic, which is caused by that of the earth, must also vary. The consequence is, that the length of the solar day is constantly fluctuating; and to get a fixed measure of solar time, astronomers have to imagine a sun moving uniformly in the celestial equator, and completing its circuit in the same time as the real sun. The time marked by this imaginary sun is called *mean solar time;* when the imaginary sun is on the meridian, it is *mean noon;* when the real sun is on the meridian, it is *apparent* noon. It is obvious that a sun-dial must shew apparent time, while clocks and watches keep mean time. Only in four days of the year do these two kinds of time coincide. In the intervals, the sun is always either too fast or too slow; and the difference is called *the equation of time*, because, when added to or subtracted from apparent time, it makes it equal to mean time. The mean solar or *civil* day is divided into twenty-four hours, the hours into minutes and seconds. A sidereal day, we have seen, is shorter; its exact length is 23 hours, 56 minutes, 4 seconds of mean solar or common time. Astronomers divide the sidereal day also into twenty-four hours, which are, of course, shorter than common hours. In the course of a civil year of 365 days, the earth turns on its axis 366 times, or there are 366 sidereal days.

The earth, then, gliding noiselessly and steadily round on its axis, is the great time-keeper, and the heavenly bodies are the pointers or indices by which we note its progress. The art of reading off the hour of the day from the heavenly bodies is necessary in the important problem of *finding the longitude* at sea.

The Seasons.—The way in which the earth's annual motion round the sun produces the alternations of the seasons will be understood from the accompanying sketch, which represents a bird's-eye view of the earth's orbit as it would be seen from the north side. At the left of the figure, the earth is seen in the position it has at the winter solstice (21st December), the upper end of the axis, or north pole, leaning directly away from the sun at an angle of 23½° from the perpendicular to the plane. Thus, the sun's rays, which can only



fall on half the surface at once, reach only to the arctic circle; and the turning of the earth on its axis has no effect to bring any part of the space within that circle into the light. On the north temperate zone, the sun's rays fall slanting and with little effect; and the part within the light at any one time is small compared with the part in darkness, which causes short days and long nights. As the earth moves round in the direction of the arrows, keeping its axis parallel to its original position—which it does on the principle of a spinning-top—more and more of the northern hemisphere comes within the light, until, at a quarter of the circuit, when the axis is at right angles to a line drawn from the sun, the rays fall direct on the equator, and reach to both poles, so that every part of the whole surface is twelve hours in light and twelve in darkness. This is the *vernal* equinox (22d March). In the continued progress of the earth, the effect of the inclination of the axis is to turn the north pole towards the sun, instead of from it, and bring more and more of the northern hemisphere into the hemisphere of light; and when the globe comes to the opposite point from where it started, the inclination is directly towards the sun, and its rays reach 23½° beyond the pole, so that the whole of the arctic circle turns round in continual day, and the temperate zone is longer in light than in darkness—it is midsummer (21st June). The earth's progress through the remaining half of its orbit has just the reverse effect on the position of the northern hemisphere with regard to the sun's rays; at the middle of it there is another equality of day and night—the *autumnal* equinox (22d September)—and at the end, things are in the position from which they started. It is evident at a glance that the hemisphere around the lower or south pole must undergo the same vicissitudes as the northern, only in reverse order, the summer in the one corresponding to the winter of the other.

The earth is in perihelion on the 1st of January; it is then about 3,000,000 miles nearer to the sun than on the 1st of July; the sun's disk is slightly broader, and we might expect this circumstance to mitigate the severity of our winter, and to add to the heat of summer in southern latitudes. But owing to the action of the law already given, by which the velocity of a planet increases with its nearness to the sun, the earth passes over the perihelion half of its orbit in less time than over the other half, and thus the effects of greater proximity are counteracted.

It is this real motion of the earth in its orbit that causes the apparent motion of the sun in the ecliptic already described. If we conceive a wide circle, described outside the orbit, to represent the sphere of the fixed stars, when the earth is in its position marked 'winter,' the sun will appear to be at a point in this circle beyond the earth's 'summer' position; and as the earth moves towards the vernal equinox, the sun will seem to travel along the outer circle in the direction of the autumnal. It is to this plane that the orbits of all the other planets are referred; they cross it at small angles, and the points of crossing are called *nodes*.

A year, in the usual sense of the term, is the time that the sun takes to move from either equinox back to the same equinox, or from either tropic back to the same tropic. This embraces a complete circle of the seasons, and brings the earth into the same position with respect to the sun; hence it is called a solar, equinoctial, or *tropical* year. If the equinoctial points remained fixed, this period would coincide with a complete revolution of the sun in the ecliptic, or—which is the same thing—of the earth in its orbit. But, owing to a cause which it belongs to physical astronomy to explain, the equinoctial points have a slow backward motion on the ecliptic of 50″ annually; when the sun, therefore, leaving the equinoctial point Aries one spring, arrives at that point next spring, he has yet 50″ to travel before he has completed a circuit among the stars, which makes a *sidereal year*. The return of the sun to the same equinoctial point thus *precedes* its return to the same point in the ecliptic; and this fact is known as the *precession of the equinoxes*. The length of the equinoctial or tropical year is 365 days, 5 hours, 48 minutes, 50·4 seconds; of the sidereal year, 365 days, 6 hours, 9 minutes, 10·4 seconds.

The equinoxes thus retrograde 1° in 71·6 years; and in 25,868 years they will make a complete revolution of the ecliptic. Celestial longitudes being counted from the point Aries, are slowly increasing: since the first catalogues were formed, the longitudes of the fixed stars are all greater by 30°.

The Calendar.—How the civil year, which must contain an exact number of *whole* days, is adjusted to the natural year, which contains fractions of a day, is explained in CHRONOLOGY.

THE MOON.

Next to the sun, the moon is to us the most striking of all the heavenly bodies. Its disk is almost equal to that of the sun, the mean apparent diameter being 31′ 7″. The real diameter is 2153 miles.

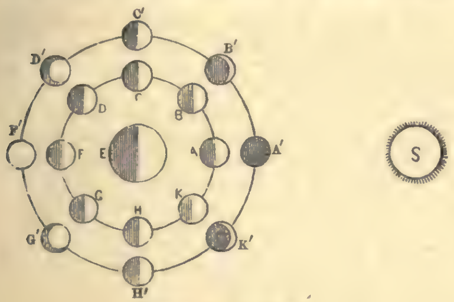
The moon's orbit being elliptical, and the earth in one of the foci, its distance varies to the extent of 26,228 miles; and this causes a corresponding variation in its apparent diameter. The moon's disk is thus sometimes larger than that of the sun, so as to cause a total eclipse of the latter, when it passes over it. The moon's path in the heavens does not coincide with the sun's path or ecliptic, but crosses it at two opposite points, at an angle of 5° 9′. These two points are called the *moon's nodes*. These points change their position, so as to make a complete revolution of the ecliptic, in a retrograde direction, in 18·6 years. When the moon is nearest to the earth, it is in *perigee;* and when at its greatest distance, it is in *apogee*.

A month.—The moon goes round the earth in her orbit in about 27⅓ days; and this motion makes her seem to us to move eastward among the stars at the rate of a little more than the length of her own apparent diameter in an hour. The time that the moon takes to make one complete revolution round the earth—that is, to return to the same place among the stars—is called a *sidereal* month or lunation. But while the moon is performing this journey, the sun has also advanced, though at a slower pace, in the same direction; and it takes the moon upwards of two days more to overtake the sun, as it were, and get again into the same situation with respect to that luminary and the earth. When it has done so, it has

completed a *synodic* revolution. The synodic period or lunation, then, is the period between two new moons, or two conjunctions of the sun and moon; it is the lunar month, and its mean length is 29 days, 12 hours, 44 minutes. The sidereal month is 27 days, 7 hours, 43 minutes.

The moon, besides revolving round the earth, also turns on its own axis, and, by a remarkable coincidence, the rotation on the axis is completed in exactly the same time as the revolution in the orbit; which is probably the case with all other secondary planets. In consequence of this coincidence, the same side of the moon is always turned towards the earth, as is evident from her surface presenting constantly the same easily recognised marks in the same positions.

Phases of the Moon.—The light of the sun, falling upon the moon, is partly absorbed into its body; but a small portion is reflected or thrown back, and becomes what we call *moonlight.* The illuminated part, from which we derive moonlight, is at all times increasing or diminishing to our eyes, as the moon proceeds in her revolution round our globe. When the satellite is on the opposite



Phases of the Moon:

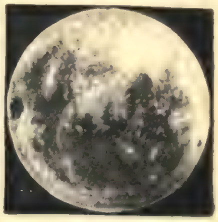
A, B, C, D, F, G, H, K, appearances presented by the moon to an observer situated at the pole of her orbit; A', B', C', D', F', G', H', K', 'phases' of the moon at the end of each eighth part of her course; S, position of sun; E, position of earth.

side of the earth from the sun, or in *opposition*, we, being nearly between the two, see the whole of the illuminated surface, which we accordingly term *full-moon.* As the moon advances in her course, the luminous side is gradually averted from us, and the moon is said to wane. At length, when the satellite has got between the earth and the sun, or into *conjunction*, the luminous side is entirely lost sight of; the moon is then said to *change.* Proceeding in her revolution, she soon turns a bright edge towards us, which we call the *new-moon.* This gradually increases in breadth, till she is one quarter of her circuit from the sun, or in *quadrature*, when half the disk is illuminated, and it is then said to be *half-moon.* The luminary, when on the increase from *new* to *half*, is termed *crescent* (increasing); when between half and full, it is *gibbous* (hump-backed).

In the early days of the new-moon, we usually see the dark part of the body faintly illuminated, an appearance termed the *old-moon in the new-moon's arms.* This faint illumination is produced by the reflection of the sun's light from the earth, or what the inhabitants of the moon, if there were any, might call *earth-light.*

It is estimated that it would take 547,513 full-moons to give as much light as the sun; which is twice as many as would find room in the whole half-sky. The moon's rays were till recently believed to be without heat; but by concentrating them in a lens of three feet diameter, the Italian philosopher Melloni obtained a sensible elevation of temperature.

The *physical condition of the moon* is in many respects remarkable. As a powerful telescope shews an object as if it were a thousand times nearer than it is, we can view the moon as if it were only 240 miles off, and thus the geography of its surface is pretty accurately known. The darker patches, which used to be considered seas, are found to be smooth planes, and have all the appearance of having once been sea-bottoms. The brighter parts are mountainous.



The Moon, photographed.*

'The mountains of the moon are not mountains, in the common acceptation of the term; they are circular pits, hollowed out into the lunar substance, and surrounded by a ring-shaped elevated border, more or less abrupt and broken. There are some that are not more than 300 or 400 yards across; others exceed 100 miles.'

These circular mountains are denominated, according to their magnitudes, *Walled Plains, Ring-mountains, Craters*, and *Holes.* The most remarkable of the ring-mountains is that called Tycho, after the illustrious Danish astronomer. The enclosure is a circle forty-seven miles in diameter, and the inner side of the ridge is as steep as a wall, and 16,000 feet high, while the height above the surrounding surface outside is only 12,000 feet. On the floor of the enclosed hollow stand a few isolated hills, one of them nearly a mile in height.

The heights of the lunar mountains are measured by means of the shadows they cast during the phases. More than a thousand have been thus determined, several of which reach a height of 23,000 feet. One peak named Dörfel is 26,691 feet high. Considering that the moon's diameter is little more than one-fourth that of the earth, the lunar mountains are thus on a much grander scale than the terrestrial. The mountains of the moon have in many respects a volcanic character; but no trace of an *active* volcano has yet been discovered. In addition to these ring-shaped hollows, there are long trenches with raised sides, called *rilles*, and bright *rays*, proceeding from a centre, like cracks, the nature of which is a mystery.

The moon is ascertained to be without any atmosphere; nor is there the least appearance of liquid of any kind, although the surface would seem to have been at one time partly covered with water. The direct rays of the sun will thus shine for fourteen days with a fierceness far beyond anything experienced on the earth; but there can be no accumulation of heat, and on the unilluminated side the cold must be for other fourteen days more rigorous than on the summits of our loftiest mountains. The present cold and dead appearance of the moon's surface, compared with what it must once have been, is accounted for by supposing that the original heat of the moon,

* Copied by permission of Messrs Smith, Beck, and Beck, from Warren De la Rue's photograph.

owing to its small size, has been dissipated into space.

The Moon and the Weather.—It is an almost universal belief that the changes of the moon influence the weather; but when put to the test of accurate observation, this opinion is found to be completely groundless: there is, in fact, no correspondence whatever between the changes of the moon and those of the weather. See METEOROLOGY.

ECLIPSES.

Eclipses are caused by the positions of the earth and moon with respect to each other and to the sun. An eclipse of the sun takes place when the moon is between the sun and earth; and an eclipse of the moon is the result of the earth being between the sun and moon.

The accompanying figure represents two positions of the moon: in the one she is in the earth's shadow, and totally eclipsed; in the other, her shadow is falling upon a part of the earth's surface, and eclipsing the sun to that part. Within the limited circle on which the moon's shadow, or *umbra*, falls, no part of the sun is seen, or he is in *total* eclipse; within a larger space round that spot, the moon seems to cover only part of the sun's disk, making a *partial* eclipse; and this space is within the *penumbra*, as it is called. When the moon happens to be so far distant from the earth that the cone of the shadow falls short of the earth, then a spectator standing immediately under the apex, or point, sees the moon covering

the middle part of the sun's disk, and leaving a ring of it visible. This is an *annular* eclipse.

It is only when the moon is in one of her nodes, or within a limited distance from it, that there can be an eclipse either of sun or moon. Now, the motions of the two orbs are such that there *must* be annually *two* solar eclipses, and there *may* be *four*. The limits for a lunar eclipse are shorter, and a whole year *may* elapse without one occurring. There are thus more solar eclipses than lunar, though the general impression is to the contrary. This arises from the circumstance that, whenever an eclipse of the moon occurs, it is seen at all places where the moon is above the horizon, and the atmosphere unclouded; whereas an eclipse of the sun is confined to a limited tract.

These eclipses, like all other things about the heavens, can be predicted with almost perfect accuracy. It is also possible to calculate backwards, so as to find the probable date of remarkable eclipses recorded to have happened in antiquity.

The inferior planets, Mercury and Venus, sometimes cross the sun's face, on which occasion they may be traced by a telescope as a dark speck moving from one edge over to another, and then disappearing. These are *transits*, and are of importance in ascertaining the sun's parallax and distance.

In times when people's fates and fortunes were predicted from the positions of the planets at the hour of their birth, much stress was put upon *conjunctions* and *oppositions*. When two bodies are in the same quarter of the heavens, so as to be near one another, or have the same *longitude*, they are said to be in *conjunction;* when they are half a circle apart in longitude, they are in *opposition*. Astronomers use the sign ☌ to indicate conjunction; and ☍ to indicate opposition.

COMETS.

'Comets,' says Humboldt, 'at the same time possess the smallest mass, and occupy the largest space of any bodies in the solar regions; in their number, also, they exceed all other planetary bodies, except, perhaps, aërolites, amounting to many thousands at least.' Comets have usually two parts—a body or head, and a tail. The head has the appearance of a round nebulous mass of light, with usually a brighter part in the centre called the nucleus, but so far from containing anything solid, that the smallest stars are seen through the densest part of the substance. The tail is a still lighter luminous vapour, surrounding the body, and streaming far from it in a direction generally opposite to that in which the sun is situated, as if repelled by that luminary, and often curved. A vacant space has been observed between the body and the enveloping matter of the tail, which also appears sometimes less bright along the middle, immediately behind the head, as if it were a stream which the head had parted in two.

Unlike planets, comets shine partly, at least, by their own light, and are believed by some to be masses of white-hot gas. Others suggest a connection between comets and the rings of small bodies that produce meteoric showers (see METEOROLOGY). The tail is by no means essential to a comet; by far the greater number have no such appendage, appearing merely as a nebulous disk.

With regard to the motions of the comets, instead of revolving, like the planets, nearly in the plane of the sun's equator, it is found that they approach his body from all parts of surrounding space. At first, they are seen slowly advancing, with a comparatively faint appearance. As they approach the sun, the motion becomes quicker, and at length they pass round him with very great rapidity, and at a comparatively small distance from his body. The comet of 1843 approached within one-seventh of his radius. When near the sun, their brilliancy is greatly increased.

In moving round the sun, comets obey the same general laws that regulate the planets. They do not, however, all describe ellipses; some pass through our system in parabolas, open curves, which never return into themselves. Now, the comets that move in shut orbits, or ellipses, must return to the sun again and again, and may

therefore be considered as members of the solar system. The others are only casual visitors; unless they meet with something to alter their orbits, they can never return, but must run off into the immensity of space.

The most remarkable of the comets ascertained to return is one usually denominated Halley's Comet, from the astronomer who first calculated its period. It revolves round the sun in about seventy-seven years, its last appearance being at the close of 1835. The annexed cut represents some of the various appearances it presented on that occasion in different parts of its orbit—*a*, *b*, *c*, in approaching the sun; *d*, *e*, in retreating.

Another, called Encke's Comet, from Professor Encke of Berlin, has been found to revolve once in 3¼ years; but in this case the revolving body is found, at each successive approach to the sun, to be a little earlier than on the previous occasion, owing probably to a cause to be afterwards described. A third, named Biela's Comet, revolves round the sun in 6½ years. It is very small, and

has no tail. During its visit in 1846, this comet was seen to separate into two distinct comets, which kept moving side by side, till they disappeared. On the return of the comet in the autumn of 1852, the distance between the two nuclei had much increased. In 1770, a comet got entangled amidst the satellites of Jupiter, and was thereby thrown out of its usual course, while the motions of the satellites were not in the least affected by its proximity. This proves the extreme lightness of the matter composing comets.

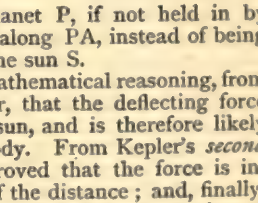
The comet now called Halley's, at its appearance in 1456, covered a sixth part of the visible extent of the heavens, and was likened to a Turkish scimitar. That of 1680, which was observed by Sir Isaac Newton, had a tail calculated to be 60,000,000 miles in length—a space two-thirds of the distance of the earth from the sun. There was a comet in 1744 which had six tails, spread out like a fan across a large space in the heavens.

PHYSICAL ASTRONOMY.

Not long after Kepler had made those remarkable discoveries which completed the view of the regular courses and periods of the celestial motions, the *causes* of the motions, or the forces whereby they are sustained, were also discovered by Sir Isaac Newton. He was the first to shew that the vast planetary balls whirl about their own centres, and fly through the celestial spaces, on exactly the same principles as a cannon-ball or a stone moves when thrown into the air. The principles of celestial mechanics, therefore, are the principles of motion discovered from the observation of bodies on the earth; they are the three Laws of Motion and the doctrines of the Composition of Forces, as illustrated under MATTER AND MOTION, and the doctrine of Universal Gravitation.

The fall of unsupported bodies to the earth is the most familiar action in nature; but it is not two centuries since Newton discovered that this action extends to the moon, the sun, and the planets. He proved that the moon is constantly falling towards the earth, and would fall into it, but for another motion she has, which is always carrying her off, and would of itself shoot her far away into space in a straight course; so that her actual circuit is the balance of two forces—one her weight, or gravity, towards the earth (*centripetal* force), the other an undying impulse to fly off at a tangent, like a whirled stone when the sling is let go (*centrifugal* force).

It was through the application partly of the laws of motion, and partly of Kepler's laws, that Newton established the universal prevalence of gravity. It being once found that the planetary motions could be kept up by a combination of forces; that is, by a force that projected the body once for all into free space with a great velocity, which, by the first law of motion, would be always kept up, whether it went off straight through space, or were compelled to go round a circle—and some second force to hold it in that circle; the great question arose: What is the *central* force—what power is it that causes the moon to fall towards the earth, instead of running off; and in like manner obliges the planets, with their immense speed, to keep constantly falling towards the sun? A planet P, if not held in by some tie, would fly off along PA, instead of being always carried round the sun S.



Newton proved by mathematical reasoning, from the *first* law of Kepler, that the deflecting force points exactly to the sun, and is therefore likely to be lodged in his body. From Kepler's *second* and *third* laws, he proved that the force is inversely as the square of the distance; and, finally, he shewed that the deflection of the moon from a straight line is exactly equal to the fall of a stone, if it were at the distance of the moon. The moon being sixty times farther off from the earth's centre than we are, gravity is there 3600 times weaker; so that the speed acquired by a stone falling one second near the earth's surface, would

be acquired only by falling an hour at the height of the moon. And it can be easily proved by calculation that the falling action of the moon is, in an hour, exactly that of a stone in a second. It being thus shewn that the moon is deflected by gravity, it was then concluded that the planets are deflected to the sun by the same cause; or that gravity is the great *central* force throughout the solar system.

After thus identifying the mechanical causes of the planetary motions, Newton deduced all the laws of Kepler from the combination of the two great forces of Gravitation and Straight Impulse. In this way he found that these laws are not strictly true, as given by Kepler, and that therefore the prediction of the places from them could not be perfectly accurate. Not only was the sun's centre not the true focus of the ellipse, that being the common centre of gravity of the sun and the planet, but he shewed that not one of the paths is an exact ellipse. If there were only one planet to the sun, that planet would describe a perfect ellipse; but if a second planet is introduced, this planet is not only attracted by the sun (and the sun attracted by it), but there is an attraction between it and the first planet which disturbs the motion of both.

In like manner, if the moon and the earth were alone in the universe, the moon would go round the common centre of gravity of the two in a perfect ellipse; but as both move round the sun, and he acts upon both, very great deviations take place from the elliptic orbit; in fact, the application of Kepler's two first laws to the moon could never predict her place with anything like accuracy.

Perturbations.—But the same discoveries that shew the defects of Kepler's laws, give the means of correcting those defects, or of calculating the disturbing influences, so as to predict what the real motions will be under those disturbances. The special disturbances are known as *perturbations* or *inequalities.* In calculating them, astronomers first suppose the case of one body revolving about a second, and disturbed in its regular orbit by a third; this is what is called the *problem of the three bodies;* the disturbing effect of each separate cause being thus found, the whole are then combined.

Masses of the Heavenly Bodies.—The theory of universal gravitation gives us the means of comparing the weights of the heavenly bodies, as if they were weighed on a steelyard. Thus the fall of the earth towards the sun in an hour can be compared with the fall of the moon to the earth in an hour; and the two quantities, multiplied by the squares of the two distances, will give the proportion between the mass of the sun and the mass of the earth, which is about 314,760 to 1. When we remember that the *bulk* of the sun exceeds that of the earth more than a million of times, we see that the matter of the sun is much lighter than the material of the earth. In the same way, Jupiter's mass is found to be 301 times that of the earth.

To find the actual density or specific gravity of the different bodies of the solar system, and compare it with a fixed standard, such as water, it is necessary to know the average density of the whole earth. This has been sought by comparing the attraction of some known body with the attraction of the globe. Thus, Dr Maskelyne attempted to calculate the attraction of a mountain in Perthshire, by finding how far it made a plumb-line to deviate from the perpendicular. In this experiment the plumb-ball was supposed to be attracted downwards by the general mass of the earth, and sideways by the mountain; and it could thus be seen how many times the whole earth surpassed the mountain in gravitating force. If the mountain itself then were measured, and its composition ascertained, so as to give the density of its rocky material, the entire mass of the mountain would be obtained, and from that the entire mass of the earth. The result of this experiment was, that the earth is, on an average, 5½ times denser than water, or more than twice the density of granite or sandstone rock. Other experiments, of a different kind, have given much the same determination. From this we can estimate the densities of the sun, moon, planets, and satellites.

The Figures of the Heavenly Bodies, how caused.—It has already been seen that the sun and planets are, in general, round masses, with a slight flattening, which seems to be connected with the rapidity of their whirl. Now, both the general roundness and the flattening can be shewn to arise from ordinary mechanical laws, such as we see operating on the earth, provided we suppose that the planets were at one time soft, fluid masses. If a fluid mass of attracting particles be left to itself—that is, if there be no external compulsion, either attraction or pressure—it will always assume the *round* shape.

But if such a body is whirled, the matter at the surface acquires a tendency to fly off, so as to oppose the general attraction towards the centre. If the whirled body is soft or liquid, it cannot remain at rest, or in equilibrium, in its round form, inasmuch as the matter at the equator, having a greater velocity than elsewhere, is rendered lighter by its centrifugal tendency, and is not a sufficient balance for the matter at the poles. To restore the balance, there must be a greater depth from the equator to the centre than from the poles to the centre; in other words, the equatorial width must exceed the polar width, which is what we actually find in all the revolving bodies. The planets also that revolve the most rapidly, as Jupiter and Saturn, are found to be the most elliptical.

Precession of the Equinoxes.—It has been already explained in what this consists. The cause is to be found in the combined action of the sun and moon on the protuberant mass of matter accumulated at the earth's equator. The exact nature of this action is too complex for description here; but combined with the rotation of the earth on its axis, the result is the regression of the equinoctial points above mentioned; while, as a necessary consequence, the celestial pole describes, at the same rate, a circle among the stars round the pole of the ecliptic at a distance equal to the obliquity of the ecliptic. Its motion, however, is not quite uniform or straight, but in a waving line, alternately approaching and receding from the pole of the ecliptic. This secondary disturbance, which is caused by the fluctuating position of the moon's nodes, is known as the *nutation* of the earth's axis.

The poles of the earth do not, then, point always to the same places among the stars. The present position of the north pole is within a degree and

a half of a bright star in the constellation of the Lesser Bear. Its motion will bring it gradually nearer until it is within half a degree of that star, after which it will recede from it. Its course may be traced by drawing a circle on a celestial globe round the north pole of the ecliptic, at the distance of 23½°. The celestial pole describes this circle in 25,868 years. Twelve thousand years hence, it will be near one of the brightest stars in the heavens, called α Lyræ, which will then be the pole-star.

Stability of the System.—It is natural to inquire whether the numerous perturbations which all the bodies are subject to, are such as in the long-run to overthrow the present arrangements of the system. Now, so far as has yet been positively ascertained, the total effect of all the mutual disturbances has no such tendency. Though there are secular variations that may go on increasing for thousands of years, it has been shewn that they will decrease continually for periods of like duration, and the limits within which this secular oscillation is confined are in all cases extremely narrow.

Two causes are pointed to as likely to produce permanent changes in the planetary motions. 1. It is generally held by philosophers, that space, instead of being perfectly empty, is everywhere filled with an exceedingly thin medium, which they call *ether*. Now, however slight the resistance this may offer to bodies moving in it, yet, if it exist at all, it must tell in the end, and will have the effect of contracting the orbits of the planets, and bringing them nearer and nearer to the sun. Such an effect would be most powerful in the case of light bodies like comets; and, accordingly, some of the short-period comets have been observed to return to the sun in a shorter period each successive revolution. In the case of the planets, no such effect has yet been appreciable, owing to their much greater mass. 2. The tidal wave moves westward on the earth's surface, contrary to the direction of the earth's daily motion; it is thus believed to act like a friction-break on a wheel, rendering the daily rotation slower, although by a quantity so small, that it has not yet been ascertained with certainty.

SIDEREAL ASTRONOMY—THE FIXED STARS.

The first thing that strikes us about the stars is their difference as to brightness. They can be classified according to this feature. The most brilliant are said to be of the first *magnitude;* the next of the second; and so on. The smallest stars visible to the naked eye are of the sixth or seventh magnitude. The number of stars visible in one hemisphere may be about 2000, making in all 4000. About twenty-four are reckoned of the first magnitude. By using telescopes, a vast mass of new stars come into view, which are reckoned as far as the seventeenth magnitude; the numbers and closeness increasing with every increase of the telescope's power.

From the earliest times, the stars have been divided into groups called *constellations*, which were named from fancied resemblances to animals or other figures. Thus, a group in the northern part of the sky is called *Ursa Major*, or the Greater Bear. From the figure of the seven more conspicuous stars, it is sometimes called *the Plough*. Another well-marked group is called after the mythical personage *Orion*. Individual stars are indicated by the letters of the Greek alphabet or by numbers, as η *Ursæ Majoris* (in the tip of the tail of the Greater Bear), 24 *Comæ*. Some remarkable stars have names, as Aldebaran (α *Tauri*), Sirius (in the nose of Canis Major). By means of a celestial globe, or a set of star-maps, the more conspicuous constellations may be soon recognised.

The stars are believed to be so many suns, shining by their own light, and being each perhaps the centre of a system of planets, the abodes of sentient and intelligent existence. Their immense distance reduces them all equally to mere points of light; in the most powerful telescopes they shew no *disk*, and differ from one another, not in *magnitude*, properly speaking, but in brilliancy. Notwithstanding this seeming inaccessibility to observation, the spectroscope makes known to us with almost certainty not a few facts regarding their physical constitution. They have white hot cloudy photospheres like the sun, and contain pretty much the same substances; thus Sirius has been ascertained to contain sodium, magnesium, iron, and hydrogen.

For a long time the distances of the fixed stars were believed to be immeasurable. More refined modes of observation have recently detected the parallax of several stars, and determined positively how far off they are. To state these distances in miles conveys no idea. It is better to take some large unit, such as the distance light travels in a second, which is 186,000 miles; we can then give the distance of a star in the time its light takes to reach us. The sun's distance is sometimes taken as a standard. The nearest distance yet measured is that of a fine double star in the southern hemisphere (α Centauri), calculated at 224,000 distances of the sun, which it takes light three and a half years to traverse. 'From the measurements already made, we may say that, on the average, light requires fifteen and a half years to reach us from a star of the first magnitude, twenty-eight years from a star of the second, forty-three years from a star of the third, and so on, until, for stars of the twelfth magnitude, the time required is 3500 years.'—*Lockyer's Astronomy.*

Variable Stars.—Some stars undergo periodical increase and diminution of lustre, and are known as *variable* stars. There are several instances also on record of stars which have come into sight for a time, and then gradually vanished, to which the name of *temporary* or *new* stars has been given; the latter phenomenon, however, is no doubt only an extreme case of the former, the period being long, and the diminution of lustre excessive. The star Omicron, in Cetus, is a remarkable instance of a variable star. It goes through a series of variations in a period of about 330 days.

The analogy of our sun is thought to afford an explanation of this phenomenon. The sun is clearly a variable star, his light and heat varying with the increase and diminution of the spots on his surface, which follow, as we have seen, a period of ten years. The observations of Balfour Stewart and others go far to prove that the frequency of sun-spots is regulated by the position of the nearer planets. Mr Stewart holds that 'the approach of a planet to the sun is favourable to

increased brightness, and especially in that portion of the sun which is next the planet.' We have only, then, to suppose that a variable star has a very large planet revolving round it at a short distance; this will cause the part next the planet to be brighter than the rest; and thus the star will vary with a period equal to that of the planet.

Double and Multiple Stars.—Another variety in the nature of these luminaries is their being in some instances not *single* stars, as they appear to the naked eye, but a group of two or more, evidently, from their motions, forming one system. The star Castor, one of the Twins, is found, when much magnified, to consist of two stars, of between the third and fourth magnitude, within five seconds of each other. Upwards of 6000 such groups have been observed. It is generally observed that they move round each other within a certain time, and in elliptical orbits; the revolution of Castor, for instance, is supposed to be accomplished in 252 years.

Proper Motion of Stars.—When we speak of the stars being *fixed*, it is only as compared with the planets. There is no such thing as absolute fixity in the universe. Besides the revolutions of the double stars, a great many stars have been observed to be slowly but constantly carried away from their places in the heavens. This *proper motion*, as it is called, has in one instance shifted the situation of a star in the heavens, in the course of fifty years, over $\frac{1}{17}$th of a degree. Founding upon these displacements of the stars, it has been concluded that our sun, accompanied by his attendant planets, is in motion towards a region of space in the direction of the constellation Hercules.

Milky-way.—The stars are very unequally scattered over the sky. We may always observe a whitish band arching the heavens, called the *Milky-way*, which appears to the eye, and still more to the telescope, as a dense mass of starry dust. From this appearance it is inferred that the stars forming our firmament do not extend indefinitely into space, but are limited in all directions, the mass having a definite shape. Herschel conceived the stratum to be thin in proportion to the length and breadth, and that looking through the mass of stars forming the depth in these directions, gives the appearance of the Milky-way. As the Milky-way divides into two branches, there must be a bifurcation of the stratum. Our place in the system is conceived to be not in the centre, but nearer to one end and to one surface.

Remote Star-systems, Nebulæ.—From the grand idea of the solar system, we thus rise to the vastly grander idea of a *stellar* system, composed of countless myriads of solar systems, many of them, perhaps, surpassing our own in magnitude, and held together by the universal bond of gravitation. But this star-system, which we may call our own universe, inconceivably vast as it is, is but an item of the heavenly inventory. Far beyond its bounds, the modern telescope has descried similar systems in great numbers, each hanging in some tolerably defined shape in the depths of space.

A few of these remote systems are visible to the naked eye, as faint luminous spots in the heavens; but by means of powerful telescopes, thousands of them have been observed and catalogued. They are generally spoken of collectively as *nebulæ*, from their cloud-like appearance. Many of them are resolvable into individual stars, even with a moderate telescope, but others were found to resist even the powerful telescope of Sir William Herschel; and he accordingly made a distinction between clusters of stars, or resolvable nebulæ, and nebulæ properly so called, which presented no appearance of stars. These last were conceived to be elementary sidereal matter in a diffused and gaseous form—matter in the course of being condensed to stars and systems. But when the still more powerful telescope of Lord Rosse shewed that several so-called nebulæ, hitherto irresolvable, were really groups of stars, the nebular theory was thought to be overturned; for although many still resisted resolution, this was attributed to extreme distance, and the want of sufficient telescopic power. That wonderful instrument, the spectroscope, however, has recently reinstated the nebular theory, by shewing that among these appearances there are real nebulæ, devoid of solid or liquid matter, and consisting of masses of glowing gas—apparently nitrogen and hydrogen.

Nebulæ and Clusters.

These nebulous-looking objects, whether star-clusters or true nebulæ, present the most remarkable and sometimes startling shapes, of which a few specimens are represented in the figure. It is believed that Lord Rosse's telescope has brought within our ken objects whose light must take sixty thousand years to reach us!

GEOLOGY.

NATURE OF THE SUBJECT.

WE have most of us stood at the base of a great cliff, and looked upwards with awe at the rocks exposed on its weathered front. Such a sight might suggest many strange and interesting inquiries. How did these rocks come to be where they are? Of what are they composed? When were they formed? Whence the material for the vast thickness of rock that composes the crust of the earth? Whence have come the varied substances that form our limestones, coals, and sandstones? Whence also the strange shells, plants, and animals that a closer examination of their structure reveals? Are these the remains of bygone living organisms, or are they only marks in the rocks themselves? If they were once living creatures, what were their structure and habits? Such questions suggest themselves to every thinking person, and such questions Geology undertakes to answer.

Geology, from the Greek *gē*, the earth, and *logos*, a description, is, according to its name, a description of the earth. It examines the various rocks that compose its crust, and seeks to explain their appearance, form, structure, relative position, formation, age, and distribution throughout the globe. It also inquires minutely into their contents, animal, vegetable, and physical; the causes of their imprisonment in their stony tombs; and the structure and habits of the creatures there found. It pictures forth the physical history of the globe during the successive epochs through which it has passed, with their varied scenery and inhabitants, the formation of its many strata, and the structure and progress of the organic forms that successively waved in its atmosphere, moved over its surface, or swam in its seas. In short, it is the province of geology to describe the whole natural history of the globe during the various ages of the long past; and it includes the ancient zoology, botany, mineralogy, and geography of the earth, whose present conditions are the result of the numberless changes through which it has passed in these geological eras. The past it seeks to interpret solely by the present, assured that the laws of nature are invariable and universal, and that causes operating now produced like effects in the primeval earth.

ROCKS, THEIR KINDS, STRUCTURE, AND DISPOSITION.

In order to speak with precision in our study of this subject, it is necessary to have a distinct idea of what a rock is in geology, and to understand certain things regarding the kinds, structure, and arrangement of rocks.

What a Rock is in Geology.—In geology, the word rock has a wider meaning than it has in common language, where it means a mass of stone of considerable size. In this science, the word rock is used to designate *any of the materials that compose the crust of the earth*, of whatever size and softness they may be. Geologists reckon sandstone, marble, quartz, granite, and limestone to be *rocks*, as others do; but they also speak of coal, gravel, chalk, sand, salt, peat, and like soft and broken substances, as *rocks* or rock-formations.

Kinds of Rocks.—Rocks have different names, according to their appearance and structure. Every one knows what *sand* is, and that it varies greatly in fineness. The most of the sand we see is composed of small particles of rock ground to powder, but it often consists, as we shall afterwards learn, of numberless very minute shells. *Sandstone* is the usual rock of which houses are built, and which, in thin layers, is used for pavement. This rock is more common than any other, and has many varieties, and is, of course, so called because it is composed of particles of *sand* that have been made to cohere. When the particles of the sandstone are somewhat larger and sharper, the rock is called *grit*, from the particles having been *grated* down or broken: the rock of which millstones are formed is called millstone-grit, and its value depends on the hardness and sharpness of the grains of which it is composed. When the particles are larger still, and form small stones that do not cohere, the rock is called *gravel;* and when yet larger and more rounded, *shingle*, examples of both of which occur on the sea-beach. A mass of broken angular stones thrown up in a heap, as by a river after a flood, is called *rubble.* A stone when small is called a *pebble;* when large, a *block;* and when rounded and worn, a *boulder*, because it is *ball*-shaped. The fine sediment at the bottoms of rivers, lakes, and pools is composed of ground mineral, animal, and vegetable matter. When this is tough and plastic, it is called *clay*, because it *cleaves* or sticks; and the whole accumulation of mud, clay, and sand at the bottom of any water, is called *silt.*

The remains of vegetable matter found in various parts of the country, and used as fuel, are known as *peat;* and *coal* is nothing but such vegetable matter changed by heat, and hardened into rock by pressure. *Limestone* is the name given to the hard rock which, after being burned in a kiln, forms *lime.* When the limestone is hard and crystalline, it forms *marble*, which is of different colours, from deep black to pure white, and often beautifully variegated. *Chalk* is a variety of limestone, and obtains its name from this fact; the word chalk being another form of the Latin *calx*, lime.

Common *slate*, used for writing on and for roofing, is composed of thin layers of hard rock, of which some of our highest mountains are formed. The name *shale* is applied to a kind of rock which *shells* off or splits into very thin layers, and which may be seen in great heaps near coal-pits. Thin layers of sandstone used for pavement are called *flags.* The white pebbles so common on the sea-beach, and so easily broken, are made of *quartz*, and rock formed of it is called *quartz-rock.* Some varieties of quartz, called *rock-crystals*, are very beautiful and valuable, and are reckoned precious stones, such as agate, amethyst, and topaz. *Flint*

has much the same composition as quartz, and is very plentiful in chalk. The granular rock brought from Aberdeen and elsewhere, so beautiful when polished, is called *granite*, from its being composed of *grains* of other rocks. It has two chief varieties, the gray and the red, according to the prevailing mineral in its composition. It is composed of quartz, mica, and felspar. It composes the mass of some of the chief mountain ranges, and forms part of some of the grandest scenes in nature. It is in general of igneous origin, but is certainly not always such; its origin is the subject at present of much controversy. The particles that glitter like silver in the granite are pieces of *mica*,[1] which is so named because it *shines*. A mineral very like mica in appearance, but different in composition, is called *talc*, from its feeling somewhat greasy or *tallowy* when touched.

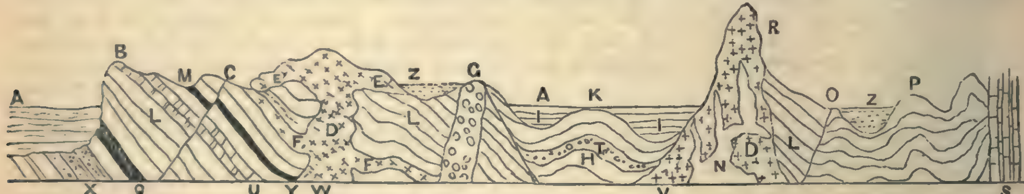
The molten matter that *flows* from volcanoes is called *lava*;[2] *pumice-stone*[3] is the *cinder* of such discharges; while the *ashes* that are thrown into the air are called *scoriæ*. In geologic times also there existed volcanoes from which lava issued; the rock this lava formed is called *trap*,[4] from lying in *stair*-like masses, as it flowed from the mountain; and one kind, *whinstone*, which is much used for roads. A common variety is known as *greenstone*, from its colour, of which Salisbury Crags, near Edinburgh, are composed. Another variety is called *basalt*, and is generally found in columns standing close together, which often form wonderful natural scenes, such as Fingal's Cave and the Giants' Causeway. Another variety is *porphyry*,[5] so called from its frequent *purple* colour, and is easily distinguished by its granular appearance. A kind of light porous rock, formed of cohering volcanic ashes, is known as *trap-tuff*, or *tufa*, a word that comes from Italy, the seat of so much volcanic action.

STRUCTURE OF ROCKS.—On examining the rocks forming the crust of the earth, we find that they may be divided into two great classes—the *stratified*, or those deposited in strata or layers; and the *unstratified*, or those not so formed. Sandstone and slate are stratified rocks; granite and trap are unstratified.

1. *Stratified Rocks*.—Any thin deposit of rock is called a *layer*, from its having been *laid down* under water; a *band*, from its being like a thin band; a *bed* or a *stratum*, when of greater thickness, from Latin *sterno*, to spread; and a *seam*, when of a peculiar character as compared with the rocks near it, as a seam of coal. *Stratum*, with the plural *strata*, is the general term for any layer of rock, and hence all rocks in layers are said to be *stratified*. Rocks that split up into very thin layers, a great number being included in the thickness of an inch, are said to be *laminated*, and the thin layers are called *laminæ*; these are formed by deposition. Slate-rocks have a remarkable tendency to split or *cleave* in one direction, which is called their *cleavage*. This in general does not coincide with the lamination, and may be at any angle. It is by the cleavage that the slates of commerce are separated. Some attribute this phenomenon to pressure, others to heat. Gneiss and other rocks have a tendency to split or *foliate*[1] into thin layers of different mineralogical character, as quartz, mica, and such like. This is called their *foliation*, and must be distinguished from their stratification and also from cleavage, which exists in rock of one mineral composition. Granite and other rocks are often split into large masses, more or less cubical, along certain lines at equal or varying distances. These lines of separation are called *joints*. They occur much in igneous rocks, as in basalt. These words should be carefully distinguished: thus shales are laminated; schists, foliated; igneous rocks, jointed; slates, subject to cleavage. When a rock is composed of rounded pebbles or boulders imbedded in other matter, it is called a *conglomerate*, and sometimes, from its appearance, *pudding-stone* or *plum-pudding stone*.

2. *Unstratified Rocks*. — Unstratified rocks assume various forms, according as they have been shot up amongst the stratified rocks; for, as we shall afterwards see, they have been erupted from volcanoes. Very often, like most volcanic substances, they are *porous* or *cellular*, like pumice-stone; frequently they form gigantic columns, when they are said to be *columnar*, like basalt; and often they are found in large *globular* or *spherical* masses, like bombs or cannon-balls.

DISPOSITION OF ROCKS.—1. *Stratified Rocks*. —When rocks lie parallel to the horizon, they are termed *flat* or *horizontal*, as A, in the following section; when at an angle to it, they are said to



Section of the Different Kinds of Strata.

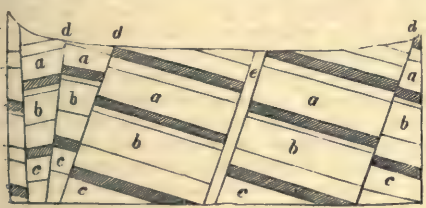
A, Horizontal and unconformable rocks.
B, Inclined strata.
C, A slip.
D, A disrupting mass.
E, Overlying trap.
F, Interstratified trap.
G, A dike.
H, Bent and rolling strata.
I, A basin or trough.
K, A ridge of rocks.
L, The dip of the rocks, 45°.
M, An outcrop.
N, Veins.
O, A fault.
P, Contorted or twisted strata.
Q, A seam.
R, Rocks tilted up.
S, Columnar basalt.
T, Conglomerate.
U, Limestones.
V, Granite, disrupting.
W, Trap.
X, Sandstones.
Y, Coal.
Z, Silt or gravel.

be *inclined* or *dipping*, as B; when one end has been thrown up by some other mass, they are said to be *tilted up*, as R; when so much inclined as to be straight up and down, they are said to be *perpendicular*, or *to stand on edge*. When inclined

[1] From Latin *mico*, to shine.
[2] From Latin *lavo*, to lave or flow.
[3] From Latin *pumex, -icis*, cinder.
[4] From Swedish *trappa*, a stair.
[5] From Greek *porphyra*, purple.

[1] From Latin *folium*, a leaf.

rocks come to the surface, they are said to *crop out*, and the exposed edge is therefore termed the *outcrop*, as M; the angle at which they are inclined is called the *dip* of the rocks, and is measured by the number of degrees from the horizontal in any direction, as 60° S.; and the line of the outcrop along the surface is termed the *strike* or *line of strike*, because it strikes or runs across the country. When the strata are not straight, they are said to be *bent* or *curved;* and when greatly bent, *twisted* or *contorted*, as P. When all the strata in a series lie at the same angle, they are called *conformable;* when at different angles, *unconformable*, as at A. Sometimes certain strata seem to have slipped down or to have moved up, so that rocks that should be opposite to one another are not so. The portion that has slipped is naturally termed a *slip*, as C; that which has been heaved up, an *upheaval* or *hitch:* where the strata at the slip lie at different angles, the slip is called a *fault*, as O. All such displacements of strata are known as *dislocations*, and they are much more frequent than the regular disposition of rocks on the surface of the earth. Below is a good example of such dislocations in coal strata, where they are abundant. The *slips* are marked *d;* a *dike*, of trap, *e;* *a*, *b*, *c*, shew the strata that have been torn up; the dark bars are coal seams. When strata are bent in wavelike undula-



Dislocations of Coal Strata.

tions, they are said to *roll*, as H; and the hollow or concave portions are termed *troughs* or *basins*, and the elevated portions *ridges*, as I and K.

2. *Unstratified Rocks.*—These rocks are thrown up amidst the stratified, and assume different positions according to the manner of their upheaval. Where they throw the strata into various angles, the rock upheaved is termed the *disrupting* mass, as V; at other times, they overlie the other rocks, and are then called *overlying*, as E; they are also interjected *between* the other *strata*, and are said to be *interstratified*, as F. Sometimes they intersect the other strata by masses like walls, which are called *dikes*, as G; and sometimes the disrupting mass breaks into branches, which are called *veins*, as N.

When a broad face of rock is exposed, and the different rocks shewn, as in a cliff on the seashore, a railway-cutting, or a quarry, such exhibitions of strata are called *sections;* and these may be delineated on paper. Sections of the underlying rocks may also be made, by examining the different rocks in a country, though no section be exposed in nature.

THE CONTENTS OF THE ROCKS.

The contents of the rocks receive the general name of *fossils*, from the Latin *fossus*, dug, because they require generally to be *dug* out of the earth. Fossils may be divided into two great classes, animals and plants.

Fossil Animals.—In the rocks we discover specimens of every class included in the animal kingdom. We find corals of all kinds, and of the most beautiful structure, some branched like some of the corals of the present seas, others standing in masses on the very spots where they lived and died, their remains giving beauty to our finest marbles. We see star-like creatures of all kinds, either spreading abroad their arms or curled up at rest, as they may be seen any day during the ebb of tide. Shells of every form, size, and colour meet us at every step, as distinct as we now find them on the shore; and some formations, of vast thickness and extent, are formed entirely of the habitations of these little creatures. We may also gather crustaceans, such as the crab and the lobster, the minutest parts of their structure being perfectly preserved. We discover fishes of every kind and size, sometimes entire, as they fell to the bottom at death, or crushed and broken in the convulsions to which the rocks have been subjected. We can gather the hard scales, that defended them like armour; can form collections of their teeth, their fins, their jaws, and their eggs; and can construct them again as they swam about in the ancient seas. Insects, too, we can gather of every kind, and can see them as they flew about in the old forests, and got entangled in the resin of the great old trees. Birds, too, are found, though not so plentifully as other creatures, as, from their manner of life, they were not so easily carried down by rivers, and deposited in the mud at their mouths. We find reptiles of immense size, crocodiles, and lizards, and flying dragons, with their terrible teeth, sweeping tails, and adamantine hides. We come upon beasts of every size, from little creatures that burrow in the ground, to gigantic deer, elephants, rhinoceroses, and mammoths; and may enter the very dens in which lived beasts of prey, and to which they bore their captured victims.

These creatures differ more or less from those that now inhabit the globe, but they are members of the same classes; and catalogues of them have been formed as of those of the present day. A visit to a museum in which fossils are exhibited astonishes every one with the multitude, variety, and beauty of those fossil creatures, and especially with the wonderful preservation of organisms the most delicate and frail.

Fossil Plants.—But the vegetable kingdom is as fully represented in the rocks as the animal. We find trees of the most varied kinds, with their roots, stems, branches, leaves, flowers, and fruit. We can look with wonder on the exquisite carving on the stems of mighty trunks, hundreds of feet in height, that once formed forests as dense and impenetrable as those of the Amazon. But more, we can behold the trees standing on the very places in which they grew and waved their great branches, and can trace their roots as they penetrate the soil beneath. We can also gather plants of all kinds—reeds, mosses, rushes, sea-weeds, and beautiful ferns—preserved entire, and spread out on the rock as delicate and perfect as in the finest herbarium. These fossil plants have, like the fossil animals, been examined and classified by botanists, and we possess elaborate volumes on the botany of the remote ages when these plants

grew, similar to those on the existing flora of our globe.

Traces of Natural Operations.—But the rocks bear traces of more than all this. On them, we can see the very dints of the rain-drops of these bygone ages, and can calculate the direction and force of the showers that impressed them. We can walk over the rippled sands of the old seas, just as we can do over those we played on in childhood. We can also look on the footprints of primeval birds, as they stalked in the mud of their lake or river homes; or gaze with astonishment on the great footprints, as large as a man's hand, of the huge reptiles that waddled among the reeds by the great old rivers. We can look into the craters of extinct volcanoes, can follow the flow of the destructive lava, and can gather the ashes that once illuminated the darkened heavens. We can trace the sources of ancient rivers, and dig in the mud brought down from their mountain sources; can draw maps of the continents and seas as they existed thousands of ages past; can tell where great ocean-currents flowed, bearing huge icebergs, that grated the sea-bottom, and left their indelible traces on the granite and trap of our present hills; and can shew where mighty glaciers once existed in valleys now famed for their beauty, where the genial sun sheds its warmest rays. In short, every element in nature, whether of air, river, or ocean, has left its deepest traces on the solid crust of our globe.

AGENCIES IN THE FORMATION OF ROCKS.

Any explanation of the manner in which rocks have been formed must account for *all* the phenomena, equally of composition, structure, arrangement, and contents. We must, for instance, explain how some rocks are stratified, and others not; how some are horizontal, and others inclined; and how plants and animals have come to be imbedded in them so far below the surface. Are there, therefore, any agencies engaged in the formation of rocks *at the present time* that produce effects the same in kind with these older masses? If we find that such exist, we shall have a key by which to interpret the rock-formations of the past. Let us consider, therefore, the Rock-forming Agents.

Volcanic Agents.—The most obvious rock-formers at present in action are volcanoes. From circular openings, called *craters*[1] from their *cup-like* shape, at the summits of these mountains, there issue forth at certain times great streams of molten lava, boiling water, red-hot fragments of rock, mingled with flames, and smoke, and steam, amidst confused and thundering sounds, and the general convulsion of the surrounding country. These lava-streams, increased by ashes and other substances, are often of great thickness, sufficient to bury cities; as Vesuvius once did Herculaneum and Pompeii, and Etna did Catania at its base, where the river of lava gradually rose round the walls, finally drowning the city in its burning flood, after it had flowed twenty-four miles! Successive accumulations of such outbursts deposit immense masses of rock, in the course of ages, round the centre of eruption; so great, indeed, that the larger portions of such mountains—and some of those in America are five miles in height—are formed of the successive accumulations of the crater itself. The molten lava assumes various appearances after it has lost its heat: under water, it remains hard and compact; in the open air, it becomes porous and cindery; and in certain cases, it assumes a columnar form. All around, lie light pumice-stone, slag-like masses, fine pulverised dust, and huge calcined blocks. Now, the Unstratified rocks resemble in every feature these volcanic discharges. We meet with the compact lava in our trap and greenstone; with the cinder, in the lighter porous rocks; with the ash, in our trap-tuffs; and with the columnar, in the basalt. In exposed sections, we see the very vent through which these masses burst and overflowed the strata above; and can trace the boundaries of the ancient molten streams in the cliffs and hills that everywhere vary the surface of the country. We can also see hardening and crystallising changes produced on the surrounding strata wherever the heat of the erupted matter penetrated. We have therefore found the explanation of one great class of the rock-formations, the Unstratified, in the volcanoes scattered over the globe, that are at this moment depositing masses similar in kind to those that issued from the bowels of the earth in bygone ages. These unstratified rocks, therefore, are termed *igneous*,[1] from being produced by *fire; volcanic*, from having issued from *volcanoes;* and *eruptive*, from being produced by *eruptions*.

Aqueous Agents.—Rivers, as they flow over their channels, gather accumulations of mud, sand, gravel, and animal and vegetable remains, according to the size of the stream and the character of the country through which they pass; and these they deposit at their mouths in seas or lakes. Sometimes the amount of débris thus deposited is so great as to form large tracts of land, as at the protruding mouths of the Ganges, Nile, or Mississippi. Even in historic times, the land thus gained is of great extent. For example, at the mouth of the Po, a minor stream, the town Adria, which gave its name to the Adriatic Gulf from its extensive commerce in Roman times, is now nine miles from the sea! The mass of matter held in solution or borne along by the running water, sinks to the bottom when it reaches the sea, in a certain order. First, the heavier masses are deposited, such as boulders and gravel; then, the sand; and last, the mud. Mingled with these are various animal and vegetable remains that have been washed into the stream. Thus, every river-mouth presents an ever-growing series of beds of varying thickness and material, superposed the one on the other, and enclosing various remains of animal and vegetable life. These deposits would, in the above order, be converted, by pressure, into conglomerate, sandstone, slate, shale, and coal. Thus, again, we have found a beautiful and perfect explanation of the Stratified rocks as they are presented everywhere, by which their composition, stratification, and contents are fully accounted for. Stratified rocks, therefore, obtain the various names of *sedimentary*, because formed of the *sediment* of rivers; and *aqueous*,[2] because deposited under *water*.

Organic Agents.—But animal and vegetable

[1] Greek *kratēr*, a cup.

[1] From Latin *ignis*, fire. [2] From Latin *aqua*, water.

life is also busy in the formation of rocks. Away in the warmer seas of the Pacific, lives the coral insect or zoophyte, the skeletons of which compose the remarkable coral reefs that form the chief part of the numerous isles that stud that greatest of seas. These reefs extend thousands of miles, in broad barriers, over which the wild waves dash, or in detached groups that gradually gather material round them, and form new islands. In the rocks, we also find the remains of like corals, standing where they grew, or drifted away, and appearing as extensive formations of limestone.

Again, the bottom of the sea is covered with accumulations of minute shell-fish, of great depth and extending over wide areas, as is proved every day by soundings with the lead. The old rocks also exhibit strata identical in composition with these microscopic shells; some limestones and chalks, for example, being composed of millions to the square inch of perfect bivalve shells. Again, the sea-bottom contains beds of shell-fish, of different kinds, and of great extent and thickness. If these were to die, and be subjected to sufficient pressure, they would form a rock, exactly like the shell limestones so common in our rock-formations, and so valuable in agriculture and building.

Then we possess the remains of ancient forests in our great mosses; and luxuriant growths of swampy plants and impenetrable jungles in the mud islands of the deltas of our great rivers in the tropics. These, submerged and acted on by heat and pressure for ages, would become coal, similar to what we daily use for fuel. Thus, organic life of all kinds is everywhere busy in forming rock-masses, similar in character and appearance to those presented to our investigation in limestone, chalk, and coal.

AGENCIES IN THE ALTERATION OF ROCKS.

DISTURBING AGENTS.—Stratified rocks in their natural state would be more or less horizontal and continuous. How, then, are we to account for the tiltings, upheavals, faults, and various dislocations so prevalent among the strata? Igneous forces furnish the solution. The whole globe is subject to convulsive movements produced by internal forces, which are seen in earthquakes, and by which the ground is torn into fissures, and the solid crust made to move in mighty undulations, that destroy and swallow great cities. Extensive tracts are also sometimes suddenly raised or depressed. Sometimes, too, great yawning craters open where previously volcanic movement was unknown, and continue for a time in active eruption. In these upheavals and subsidences, sudden or gradual, of extensive tracts, we see the causes at work of the dislocations of the rocks of former times, and of the elevations and depressions that occurred throughout the geologic eras.

Again, we know that in order to the deposition of strata of any thickness, the sea-bottom must have gradually subsided: does any such gradual subsidence take place at the present time? It is ascertained, from extended observations, that on the northern shores of the Baltic, for instance, there has been a gradual rise at the rate of 4 feet in a century; and, in South America, a rise of 85 feet during the human period, at Valparaiso, of 19 feet in 220 years; while over all the world, and even round our own coasts, ancient sea-beaches may be seen at various elevations, marking former sea-levels. On the other hand, the south coast of Sweden, the coast of Greenland over 600 miles, and parts of South America for the last 300 years, have been slowly sinking; nor are the British shores free from such oscillations.

Thus, again, we see that existing causes perfectly explain the *gradual* subsidences and upheavals necessary to the formation of the rocks and to their subsequent elevation into dry land.

DISINTEGRATING AGENTS.—Every stratified rock in the immense thickness of the crust of the globe has been formed of the débris of pre-existing formations, that have been ground down and held in suspension till deposited in the layers afterwards hardened into rock. Whence, then, this immense accumulation of matter, and what the disintegrating agents?

1. *Atmospheric Agency.*—The atmosphere, by its chemical action, and by the combined effects of alternate heat and cold, wetness and dryness, is continually crumbling down all exposed surfaces, forming new soil, and thus increasing the earthy covering of the globe. The wind, also, has an incredible power of drifting and heaping up sand-hills along the shore—as in the county of Elgin, where an ancient barony has been entirely reduced to a desert through this means—and of raising the waves of the sea, and wearing the rocks through the mighty force of its swooping billows. Frost, too, is one of the quietest but most powerful disintegrating agents; for when water has percolated a mass of rock, the act of freezing exerts a great expansive force, which cracks the rock. But frost can work on a grander scale, for to its agency is due the existence of avalanches, glaciers, and icebergs; which, whether sweeping with overwhelming convulsion, or crawling down the mountain side, or floating and grating on the ocean floor, continually and with terrible effect, wear down or dash to pieces every rock that obstructs their irresistible course.

2. *Aqueous Agency.*—The most extensive aqueous agent is rain, which wears, softens, percolates, and gradually wastes away the rocks on which it falls. Rain-water also gathers under the ground in large cavities, where springs are formed, which dissolve the interior rocks, and, bursting out, deposit their solutions of lime, iron, sulphur, soda, flint, and bitumen. One of the most powerful degrading agents is, of course, the sea, which, as it beats on its rocky shores, wears, rolls, and grinds to powdery sand the flintiest rocks, and presents, as monuments of its mighty power of waste, those lofty cliffs that guard its shores. But more powerful, but less obvious agents of destruction than the sea, are seen in the many streams that everywhere traverse the land on their way to this boundless reservoir. The power of rivers in excavating and wearing away the surface of the globe, is much greater than at first thought might be supposed. Most river-valleys, however deep, have been mainly worn down by river-action, extending over immense periods of time. When we contemplate the mighty valleys, inclosed by towering peaks capped with eternal snows, that lie hid amidst the mountain solitudes of the Alps, the Andes, or the Himalaya, we may well be astonished at such a statement. But that these huge excavations have been mainly produced by the combined action of air, frost, rain, and river, has

been demonstrated beyond a doubt by a vast accumulation of facts and reasonings on phenomena in all parts of the globe. Hence, valleys thus excavated are termed *valleys of erosion*,[1] from being ground out by the powerful action of these mighty agents. This being proved to be the case even during the human period, we have little difficulty in accounting for the great denudation everywhere seen, and for the immense accumulations of sedimentary matter that forms so much of the solid crust of our globe.

TRANSPORTING AGENTS.—We have also to account for the deposition of strata in one part of the country, the materials for which have been obtained at great distances; and for the transport of immense boulders hundreds of miles from their original seats, as exhibited in all parts of the globe.

1. *Aqueous Agency.*—The most obvious agents of transport are rivers, that bear down from every part of their courses the débris deposited at their mouths. Their power of carrying masses of the heaviest materials is immense, as may be seen after a flood in the smallest streams in our neighbourhood. Waves have also a wonderful power in removing and carrying to a distance the blocks on which they daily dash. But the currents that flow through the ocean, which are but mighty ocean rivers, have the greatest power in this respect. By their means, materials of all kinds, organic and inorganic, are conveyed to incredible distances. The Gulf Stream, for instance, conveys substances from the South African coasts to those of Norway and the far north.

2. *Ice Agency.*—But the transporting influence of these currents in bearing rock-masses is greatest when icebergs are carried on their surface. These huge frost-mountains have imbedded in their mass huge blocks, which are gradually dropped over wide areas as the ice slowly melts away. The size and number of some of these transported rocks are often almost incredible. Every country exhibits such travelled rocks, which are called *erratic*[2] *boulders;* and our own little island presents no mean examples of such ice-borne masses.

But ice also acts as a transporter in the form of glaciers—those great ice-rivers that fill the upland valleys of the Alps, Himalaya, and other mountain systems. In front of every glacier, along its sides, and on its surface, are great collections of rocky fragments of every size, borne down by the ice-stream, and left as evidences of its existence when the glacier has melted away. Such collections of rocks are called *moraines*,[3] from their *mural* or wall-like aspect as seen running across a valley. The distance to which such blocks are borne is astonishing, and depends on the size of the glacier. Evidences of extinct glaciers are seen in most countries, and we may trace their remains in our own island, where now not a particle of glacier ice can exist.

3. *Igneous Agency.*—It is evident that volcanoes have a great power in throwing out masses of different materials to great distances, and of carrying many substances on their mighty lava-streams; and evidences of their power in this respect in geologic times are everywhere apparent. Sometimes the fine ashes that issue from the crater are borne by the wind to great distances, often fifty or a hundred miles, where they are deposited as a layer of finest dust; and this may account for the existence of trap-tuffs in places where no volcanic eruption seems to have taken place.

TRANSFORMING AGENTS.—Rocks have also undergone great changes in structure, character, and hardness from the state in which they were originally deposited. Thus limestone has become marble; sandstone, quartzite; coal, anthracite. Such change is known as *metamorphism*,[1] and the rocks so changed are called *metamorphic*. The chief agencies producing such remarkable transformations are these:

1. *Pressure.*—The effect of pressure is at once apparent when we reflect that by it chiefly the loose materials of rocks have been made to combine and form solid strata—as sandstone from sand, coal from vegetable remains. But pressure exercises a much greater influence than would at first sight appear. For example, the melting-point of substances is greatly affected by pressure, some substances melting with much less heat under pressure than without it, others requiring more. The metamorphosing power of heat is greatly affected by pressure. Thus chalk, by heat, becomes lime in the open air; but under pressure fuses and becomes marble. Pressure is one cause, and may be the chief cause of cleavage in slates: this is one theory, known as the mechanical; the other being that of heat, and known as the crystalline.

2. *Chemical Action.*—This is one of the most secret, but one of the most general, transforming agencies, and its influence can only be indicated here. By it, substances are held in solution, or precipitated; new substances are formed; rocks become entirely changed through the chemical affinities between their contents, or by being permeated by streams and waters bearing other soluble substances; the different materials in rocks become aggregated, and form layers or masses: in short, it manifests itself by countless secret and potent effects.

3. *Heat.*—The greatest metamorphic agency is heat, whether general or local. By it rocks are wholly or partially fused, and undergo rearrangement of their component crystals, and thus become changed in form and structure; or they are subjected to partial change of all degrees of intensity. The influence of heat is always seen more or less near igneous rocks, and the eye can follow the change from the natural rock, and note the gradual increase of metamorphism as it approaches the igneous seat. By heat the most varied transformations have been effected. Thus limestone and chalk have been changed into marble, schists into jasper and granite, sandstone into quartzite and hornstone, shales into flint and jasper, clay into Lydian stone, &c. But whole systems of rock have also been affected by heat, which are known as the metamorphic or crystalline systems. The chief metamorphic rocks are gneiss, quartzite, mica-schist, with hornblende and chlorite schists, clay-slate, and metamorphic limestone. These were originally sedimentary rock, with fossils; but the metamorphism has more or less obliterated the lines of deposit, and more or less destroyed

[1] From Latin *e*, out, away, and *rodo, rosum*, to gnaw.
[2] From Latin *erro*, to wander.
[3] From Latin *murus*, a wall.

[1] From Greek *meta*, change, and *morphē*, form.

their organisms. Hence they are characterised by great absence of fossils.

Gneiss,[1] so named from its thin layers, is a hard crystalline rock, in extremely thin bands, often twisted in a remarkable manner, and consists mainly of the same materials as granite. Quartzite is a metamorphosed sandstone, and is so called from its quartzy appearance, arising from the fusion of the sandstone. It must, however, be distinguished from quartz itself. The schists are named from their chief ingredients. Clay-slate is that most useful rock which, when split up into thin layers, forms the familiar blue slates of our roofs, and the slate and slate-pencil of our schools. These rocks are often grouped together in nature, as in the Highlands of Scotland, where they form the mass of the mountains, and enter into the grand and beautiful scenery of that picturesque region. They occur most extensively in the older formations, as the Laurentian, Cambrian, Silurian; but it must be carefully noted that metamorphic rocks are found throughout all the geologic systems up to the Recent. For example, Carrara marble, which was long thought to be primary, is metamorphic oolitic limestone; and, in the Alps, tertiary strata have been so changed as to be with difficulty distinguished from the oldest rocks.

It thus appears that the agencies now at work on our own globe are adequately sufficient to account for all the phenomena of the forming, disturbing, disintegrating, elevating, depressing, transporting, and transforming of the rock-masses that form the crust of the earth. Such being abundantly proved, and the laws of nature being uniform and unchangeable, we are not only warranted, but compelled, to infer that the same influences were at work in these bygone ages, and were the joint causes of the formation of our rock-systems as they are now presented to our eyes and subjected to our investigation.

ROCKS AS RELATED TO TIME.

The Length of Geological Periods, or Geological Time.—In studying geology, it is necessary to have an accurate notion regarding the nature of the periods spoken of. It is to be carefully noted that, in geology, time cannot be measured by years. When we examine any stratum of rock, with all its enclosed organisms, it is natural to inquire how long this mass of rock took to be deposited. We can judge of this only in the following way. From observation of river-action as at present exhibited, we see with what extreme slowness rock-masses are worn down into sand; how a thousand years make an almost imperceptible change on a boulder, and even on the gravel by the shore. Yet we know that the sandstone before us, often hundreds of feet in thickness, is composed of grains of rock ground down by water-action, transported by rivers to the sea-bottom, and deposited there till other strata were heaped upon it; and that in after-ages the grains united, and were hardened by pressure into the rock we see. What incalculable ages, therefore, must this sandstone bed have taken to be thus formed! The more we think of these slow-working causes, the more are we astonished at the enormous periods of time that must have elapsed before the formation of even the thinnest layer of rock. Geological periods, therefore, are quite indefinite in the matter of *years*. This inability to assert a definite number of years in regard to any formation, is no defect in the science, for the knowledge of this would add nothing to the conception we already have of the immense periods presented to our contemplation by geology.

[1] From Anglo-Saxon *gnidan*, to rub.

The Relative Ages of Rocks.—When we speak of the different ages of rocks, we can do so only by comparison with others. Our ideas on this point are merely relative. We can assert that one layer must have been formed before another; or that, after its formation, and before the deposition of a certain other rock, a rise or fall in the strata took place; or that, at a certain point in the series, a volcanic eruption threw up a mass of igneous rock; and make like statements based on comparison of the rocks with one another. Our conceptions, therefore, regarding the connection in age between the various rock-formations are merely relative, one rock being proved to have been formed before, or after, or during the formation of another.

The Order of the Rock-formations.—By long-continued and widely extended observations in various parts of the globe, based on numberless data of composition, structure, inclination, and fossil contents, geologists have been able to form a definite list of the various rock-formations from the earliest to the most recent, arranged in the order of time. They have divided the whole of the rocks composing the crust of the earth into sections called 'systems,' and have subdivided these again into 'groups,' in a certain well-defined order. So that when a rock is presented to their observation in any part of the globe, they can state, with more or less certainty, the system to which it belongs, and the period in the past history of the earth at which it was deposited. Regarding these rock-systems, one point is to be very strictly noted. Suppose that we represent the various rock-systems by the letters of the alphabet—the earliest by A, the second by B, and so onwards to the last and most recent, represented by Z. Now, the various rock-systems always stand in this relative historic order; so that the formation indicated by M comes after L, and before N, and cannot occur in any other relation to these two systems, wherever they may be found. At the same time, certain formations, one or more, may be wanting in some parts of the world, not having been deposited there; so that one or more systems may not be represented in these districts. Thus, L and M may be absent. What two systems will then be found together? Certainly and unvaryingly, K and N. But here the historic order is not violated, as it would be if N preceded K. The various rock-systems are, therefore, always presented in an unvarying succession in the order of their formation; although, in different parts of the globe, certain strata, and even whole systems, may not be found.

CLASSIFICATION OF THE ROCKS—THE ROCK-SYSTEMS.

We now proceed to describe, in the order of their formation, the different kinds of rocks that compose the crust of the earth, and their fossil

contents. As already said, geologists have divided all the rocks into different classes, according to their relative position and the fossils they contain. The whole of the stratified rocks are divided into eleven great systems, and each of these into separate groups, to which names have been given, more or less descriptive of the strata to which they are applied. The systems have been named chiefly from localities in which they are largely or typically developed, as the Laurentian; in some cases from important rocks they contain, as the Carboniferous; in others from their position or order, as the Recent. They are given tabularly below, with the reasons for the names, and their chief rocks, to give a definite idea and to assist the memory. This list should be carefully studied and comprehended before going farther. These systems are also grouped into three great Periods, and into two great Cycles, according to the character and advance of the organic life they contain.

ROCK-SYSTEMS.

Systems.	Reason of Name.	Characteristic Rocks.	Periods.	Great Cycles.
I. LAURENTIAN.	From the *St Lawrence* in North America.	Eozöon limestone and gneiss.	PALÆOZOIC[1] or Ancient Life Period.	PALÆOZOIC or Great Ancient Life Cycle.
II. CAMBRIAN.	From *Cambria* or North Wales.	Sandstone flags with fossils.		
III. SILURIAN.	From *Siluria* or South Wales.	Slates.		
IV. DEVONIAN and OLD RED SANDSTONE.	From *Devon* and its *red sandstone*.	Old red sandstone.		
V. CARBONIFEROUS.	From its *coal* strata.	Coal and iron.		
VI. PERMIAN.	From *Perm* in Russia.	New red sandstone.		
VII. TRIASSIC.	From consisting of *three* groups.	Magnesian limestone, rock-salt.	MESOZOIC[2] or Middle Life Period.	NEOZOIC[4] or Great New Life Cycle.
VIII. OOLITIC or JURASSIC.	From its *egg-grained* rocks, and from *Mount Jura*.	Egg-grained rocks.		
IX. CRETACEOUS or CHALK.	From its *chalk* rocks.	Chalk and greensand.		
X. TERTIARY.	From being the *third* of the old geologic systems.	Clay and marl.	CAINOZOIC[3] or Recent Life Period.	
XI. QUATERNARY or RECENT.	From being the old *fourth* system, and from being *recent*.	Peat and gravel.		

These systems we shall describe in order, beginning with the earliest, down to the most recent, giving the appearance and composition of the rocks, the uses to which they are applied, and the fossils they contain. We shall also endeavour to realise the state of the earth at each successive epoch, the scenery then exhibited, and the plants and animals that then enlivened the landscape. Below the Laurentian, another system is sometimes given as existing, called the Metamorphic or Primary or Non-fossiliferous. It seems necessary to abandon this system. As shewn (p. 22), metamorphic rocks occur in all systems. The assertion of the absence of fossils is premature, and has always proved so in regard to other rocks, and is unscientific. The term primary is objectionable on like grounds. All existing rocks, as far as yet known, seem to be comprehended under the eleven systems given above, which we now proceed to describe.

I.—LAURENTIAN SYSTEM.

Description.—Immediately above the Non-fossiliferous Metamorphic rocks lie the lowest of those that contain fossils. These have received the name of the *Laurentian System*, from their great development on the shores of the St Lawrence, in Canada. It was only quite lately, in the year 1863, that these rocks were grouped into a distinct system, from the discovery in them of certain fossil remains in Canada, having previously been reckoned metamorphic. The Laurentian System consists of certain schists, quartzose rocks, and limestones, all very highly crystallised—shewing good examples of metamorphic rocks. They form two groups, upper and lower. They contain no sandstones or shales, that occur so frequently in higher formations, such of these as once existed having been changed by heat. The limestones are very highly crystallised and metamorphosed, and of great thickness. The rocks, however, are all truly sedimentary, deposited under water, and have received their present aspect mainly through the agency of heat. They are found in Canada, Ireland, Norway, and Sweden, and, perhaps, in the north-west of Scotland.

Organic Remains.—The discovery of the fossil remains that caused these rocks to be formed into a separate system, was made in Canada, and excited interest amongst geologists, because belonging to a period when organic existence was thought impossible. The organism discovered received the name of the Canadian Eozöon[1] or

[1] From Greek *palaios*, ancient, and *zōon*, an animal.
[2] From Greek *mesos*, middle, and *zōon*, an animal.
[3] From Greek *cainos*, recent, and *zōon*, an animal.
[4] From Greek *neos*, new, and *zōon*, an animal.

[1] From Greek *ēōs*, dawn, and *zōon*, an animal.

Dawn-animalcule, and consists of minute tubes or cells that are visible only under the microscope. Some still deny that this structure is organic, and regard it as merely a mineral appearance; but these are few. The general opinion now is, that here we have the earliest life-remains yet discovered on our globe; and this is all the more certain, that worm tracks and burrows were found in 1866 in the same formation. The discovery of these evidences of organic life, so long sought in vain, shews that more minute search may result in other remarkable discoveries, and that in all likelihood the name of Eozöon will be found to be premature.

II.—CAMBRIAN SYSTEM.

Description.—Immediately above the Laurentian, lies a series of slates, schists, and crystalline limestones, called the Cambrian System. It is so named from being first most fully described as it is found in North Wales, which in Roman times was called *Cambria*. The rocks in this series are less changed than the Laurentian, and therefore the remains in them are more numerous and better preserved. They are of great thickness, and are found in Wales, Cumberland, Ireland, North America, and elsewhere. They are divided into two groups, upper and lower. Along with the older rocks beneath them, they everywhere form mighty, rugged, peaked mountains, like those of Wales; and their worn, rugged aspect is due to their being so long subjected to wasting influences from their great antiquity. All these earlier rock-formations, from the Laurentian to the Silurian, are exceedingly rich in mineral wealth, most of the precious metals being obtained from them. Shooting through their hard crystalline masses, we find veins of iron, copper, silver, and gold; and, from the presence of these metals, bare mountain tracts have teeming populations, where even the sheep with difficulty finds its scanty food.

Organic Remains.—The fossil remains are all of the very lowest kinds of life. Sea-weeds and shells of different kinds have been discovered, and some crustacea—especially one that occurs abundantly in the next formation, called the trilobite. The tracks and burrows of worms, formed in the sand of the ancient seas, may also be seen perforating these hard masses.

Scenery of Period.—During the Cambrian age, quiet seas heaved their waters as now, tenanted with shells and crab-like creatures, while waves rolled on the sandy shores, over which worms crawled, and into which they burrowed; facts interesting as shewing that creatures had then the same kinds of habits as now, and that what we can see any day along our own shores, sends us back to the distant ages when the world was young.

III.—SILURIAN SYSTEM.

Description.—The Silurian System contains rocks less changed by heat than those below, and exhibiting more abundant life. In many of those already mentioned, the metamorphism has been so great as to render it difficult to say with certainty how the rocks were originally formed, but henceforth all hesitation vanishes. They form two groups, Upper and Lower Silurian. They contain slaty sandstone, finely laminated, and often exhibiting ripple-marks; conglomerates chiefly of rounded pebbles, clays, and limestones, with corals and other fossil remains, all of great thickness. The system has received the name of Silurian from being very fully developed in a part of South Wales anciently called *Siluria*.[1] From these rocks are obtained roofing-slates, freestone for building, flagstones for paving and other purposes, limestones from which lime is got by burning, and valuable ores of lead, copper, silver, mercury, and gold.

Organic Remains.—Parts of the stems and leaves of water-plants and club-mosses, and a few sea-weeds, are found, but all scarce and much broken. No land *animals* have yet been obtained, and though it would be rash to say that they do not exist, much seems to render this very probable. But marine fossils are numerous and well marked, some of them being very beautiful. We find corals of different kinds, named according to their appearance, such as the sun, star, cup, pipe, chain, spider, and honeycomb corals. One of the commonest forms in the Silurian rocks is a very beautiful curved creature like the plume of a goose-quill, called the *Graptolite*,[2] from looking like a *pen* on the *rock;* some single, others double, some straight, others beautifully spiral. Another very abundant form is the Encrinite, a coral creature more numerous in the Carboniferous System. We find also star-fishes, one beautiful and 'almost as uncompressed as if just washed up on the sea-beach,'[3] and numerous fine shells with single and double valves, some, like the periwinkle and cockle, being abundant. But the creature that swarmed most in the ancient Silurian seas was the *Trilobite*,[4] so called from its body consisting of *three lobes* or divisions, above which was set its head with large

Coral (*Astrea*). Trilobite (*Asaphus de Buchii*).
Silurian Fossils.

double eyes, still to be found entire. It had various forms, and seems to have been very active, and was of all sizes, from mere specks to fine specimens ten or twelve feet long. Creatures like the scorpion, with toothed toes, are also obtained, and, in the upper beds, fishes interesting as the most ancient fossil-fish.

Scenery of Period.—Of the dry land, we know little or nothing, except that it did exist, and nourished certain aquatic plants and club-mosses, whose remains were floated down into the great seas. But we can see mighty oceans, in which corals flourished, and encrinites waved their lily stems. Shells were abundant, and numerous creatures gambolled in the bright sun. These seas were fringed by sandy shores, on which worms

1 Inhabited by the ancient tribe of the *Silures*.
2 From Greek *graphō*, I write, and *lithos*, a stone.
3 The *Valæaster asperinus*. See Lyell's *Student's Elements*, p. 456.
4 From Greek *treis*, three, and *lobos*, a lobe.

crawled and left their tracks; gravelly beaches, that have become conglomerates; and great beds of shells, that have given origin to thick limestones. Life gradually assumes more activity, and living forms become more numerous and elevated in the scale of existence, as we ascend in the system towards the active period that follows.

IV.—DEVONIAN AND OLD RED SANDSTONE SYSTEM.

Description.—This system of rocks has been rendered famous through the writings of several geologists, especially the celebrated Hugh Miller, and is one that in itself possesses the very greatest interest. In early geology, the Coal-measures were considered very important; and as both below and above them a great thickness of red sandstone is found, the rocks above were named the *New Red Sandstone;* while those below, being of course older, were called the *Old Red Sandstone*, or, shortly, the *Old Red.* This system consists of two types, the Fresh-water or Old Red, and the Marine or Devonian, so called from being extensively developed in Devonshire. These two types may not be of the same age, or if so, were deposited under different conditions. The Old Red is largely developed in the centre and north of Scotland, especially in Forfarshire and Caithness, where it is extensively quarried, and in parts all over the world. The name 'Old Red' indicates that the chief rock is a red sandstone, which is used very extensively for building. This also occurs in fine flags used for pavement, generally of a gray colour, yielding the famous Arbroath and Caithness pavements. The remarkable rock called Conglomerate or 'Plum-pudding Stone,' which looks as if it consisted of a consolidated sea-beach, is also extensively found at the base of the system. Like strata abroad coincide more with the Marine or Devonian than with the Old Red. They are found in many parts of the world, and extensively with fine fossils in Russia and North America. Both types are divided into three groups—Lower, Middle, and Upper.

Organic Remains.—There are fewer plant than animal remains found in this system. We find sea-weeds of different kinds, marsh-plants like our bulrushes, sedges and horse-tails, tree-ferns and reeds, &c. Late discoveries have greatly increased the number of plants, so long thought to be so meagre, to above 200, rendering this system almost half as rich as the Coal-measures in this respect. Animal remains are numerous, varied, and beautiful. There are many species of corals and shells. The tracks of certain creatures, and deep burrows, sometimes eighteen inches deep and one and a half across, made by large burrowing worms, are frequently found. Many crustaceans are obtained, one of which is a huge kind of crab, sometimes six feet long, with terrible-looking toothed claws, called the *Pterygotus*[1] or ear-wing. Reptiles are also found, two very large lizards being most frequent.

But by far the most numerous specimens of ancient life are gigantic fishes. These creatures are all covered with hard bony scales, burnished with enamel, with fierce teeth, and great fins armed with long sharp spines, with which they defended themselves or attacked their enemies.

Cephalaspis,[2] or Shield-head.

Coccosteus,[3] or Berry-bone.

Pterichthys,[4] or Winged-fish.

Old Red Sandstone Fishes.

These fishes have received different names, according to peculiarities in their structure or appearance, and have been brilliantly described by Hugh Miller, who, when cutting the Old Red Sandstone as a mason, had his attention first drawn to geology by the brilliancy of their scaly armour.

Scenery of Period.—The wide oceans in which the thin fine-grained flags were deposited must have been smooth and tranquil. Round the coral islands that rose in its gleaming waters coursed huge fierce fishes. The sandy shores became the coarser sandstone. Within tide-mark, numerous great crabs lived, and caught their prey in their toothed claws; shrimp-like creatures danced over the sands, and in them worms burrowed; the waves ebbed and flowed, leaving their ripple-marks on the rocks we now see; gravel beaches fringed the shore, where the surges rounded the pebbles and rolled the stones, helping to create our

[1] From Greek *pteron*, a wing, and *ous*, *otos*, the ear.
[2] From Greek *cephalē*, the head, and *aspis*, a shield.
[3] From Greek *coccos*, a berry, and *osteon*, a bone.
[4] From Greek *pteron*, a wing, and *ichthys*, a fish.

conglomerates; rain-showers fell, and left their impressions on the sandy bays pelted with their drops; forests of sea-weed waved in the green waters and on the rocky reaches; and shells adorned the rocks. Into the seas flowed great rivers, whose banks were fringed with reeds and flags; ferns waved on the hill-side, tree-ferns reared aloft their feathery plumes, and broad-leaved plants clothed the surface of the landscape; while large reptiles roamed through the forests, or crushed the reeds by the river-sides.

V.—CARBONIFEROUS SYSTEM.

Description.—Above the Devonian rocks lies a series of strata perhaps more generally known than any other, as they afford us what is so necessary to our comfort, the remarkable combustible stone called coal. They receive the name *Carboniferous*[1] from the fact that they contain *coal*, although they furnish many other important products. These rocks are found in most regions of the globe; but in none are they more fully developed, compared with the size of the country, than in the British Isles. They consist of sandstones, limestones, shales, clays, ironstone, and coal. The sandstone is of various qualities and colours, some of it very valuable and durable; the beautiful stone of which the New Town of Edinburgh is built is from this system. The limestones are largely developed, and are of the greatest service for building and agriculture. The shales have of late become very valuable, as from them are distilled oils and other substances, including the celebrated paraffine oil and candles. The ironstone is of the very greatest value, and contributes very largely to England's wealth.

It must not be thought that coal is found only in the Carboniferous rocks. Coal, being chiefly compressed vegetable matter, may be found in any rock-system in which plants are preserved. It is accordingly found in other systems, and often in great abundance. For example, the coal-fields of Virginia, some thirty or forty feet thick, belong to the Oolitic; and coal of various kinds can be obtained, more or less, from most systems.

The same is true of other products, such as limestone, sandstone, and iron, which last, though found in greatest abundance in this system, yet occurs in many others from the earliest.

The Coal-strata are divided into three great groups—the Upper and Lower Measures, and a thick deposit of limestone, which separates them, known as the Mountain or Carboniferous Limestone. The Upper Coal-measures are also called the True Coal-measures, as they contain the greatest amount of workable coal; the Lower Coal-measures consist chiefly of sandstones and shales. The Mountain Limestone is so called because where it is most largely developed, as in Yorkshire, it rises into hills with great limestone cliffs.

The industrial products of this system are numerous and important. We find coal of all kinds for household purposes and gas; iron, sandstone, limestone, and fireclay. From the shales are obtained alum and the remarkable paraffine oil. So abundant in America and elsewhere is this ancient oil, that when the earth is bored, a flood of it issues forth yielding thousands of gallons daily.

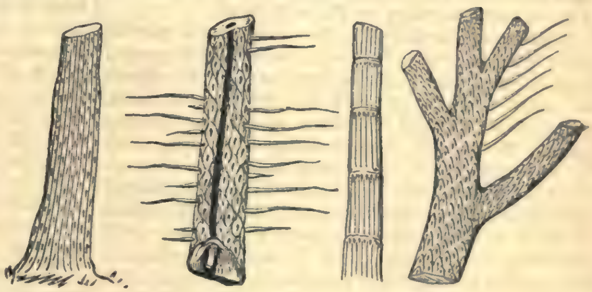
Organic Remains.—The organic remains found in this system are very abundant and remarkable. Plants are numerous, varied, and beautiful. Ferns are found with the most perfect fronds, as distinctly traced upon the rock as a modern dried fern on the pages of a book. We find also large and beautiful club-mosses exquisitely exhibited. But the most luxuriant and beautiful of all are the great pine-like araucarias, the fruit[1] of which

1 2 3 4

Carboniferous Plants.

1, Branch of *Asterophyllites foliosus*, a kind of reed; 2, 3, 4, Ferns.

may, in some places, be gathered by the bushel; the tree-ferns, and tall reeds that grew in boundless swamps and jungles along the banks of the rivers, that swept in mighty volume to the carboniferous seas. We see the *lepidodendron*[2] or scale-tree, with its pine-like leaves, beautiful scaly bark, and great cones,[3] from which the seed of the ancient pine may be gathered in hundreds to this very day; the *sigillaria*[4] or seal-tree, with its seal-stamped trunk and great pitted and branched root, called *stigmaria*,[5] long thought to be a tree of a different species; the *calamite*[6] or



1 2 3 4

Carboniferous Trees.

1. Sigillaria; 2. Stigmaria, root of Sigillaria, with rootlets attached, and pith; 3. Calamite; 4. Lepidodendron.

[1] From Latin *carbo*, coal, and *fero*, to bear.

[1] Called *Trigonocarpum*, from Greek *treis*, three, *gonē*, a corner, and *carpos*, fruit.
[2] From Greek *lepis*, *-idos*, a scale, and *dendron*, a tree.
[3] Called *lepidostrobi*, from Greek *lepis*, *-idos*, a scale, and *strobilos*, a fir-cone.
[4] From Latin *sigilla*, a seal.
[5] From Latin *stigma*, a mark.
[6] From Latin *calamus*, a reed.

reed, rising high into the air, like the bamboo, with its joints and leafy branchlets; and many more equally beautiful and well preserved.

The animal remains found are numerous and strange. Corals are abundant and beautiful. But no sea-creature was more common than the *encrinite*,[1] which rose on its long jointed lily-like stalk, and head with its hundred fingers, that moved on all sides to secure its prey, like the anemone of our own seas. The remains of encrinites are in some places so abundant as to form thick beds of limestone, called Encrinital Limestone; and when these, hard as marble, are polished, they present a most beautiful surface, through which is seen the exquisite carving of the encrinite stars. The little joints of the stems are often found detached, with a hole through the centre; these are known as Fairy Beads and as St Cuthbert's Beads; and when strung together, were used as a rosary, and no more beautiful ornament was ever hung round the neck of a saint. We also find star-fishes and sea-urchins; and the spines of the latter may be seen running through the limestone like threads of burnished silver. The shells are very numerous and varied; univalves and bivalves of both sea and land being everywhere found, and some of these can hardly be distinguished from shells gathered on our own shores, so perfect are they in form, colour, and structure. They may be detached from the rock, and collections made of them as easily as of modern shells. We find also crustaceans of different kinds; and the last trilobites are found in the Coal-measures. Fishes are numerous and formidable, but less so than in the Old Red Period. Reptiles in both salt and fresh water have also left their remains, and their footprints may be seen on certain sandstones, as distinct as if made but yesterday on the soft mud.

Scenery of Period.—In this remarkable period there stretched wide shallow seas, in which sported huge sharks, and whose waters washed the shores of many islands, guarded by great coral reefs, where the beautiful encrinite spread its waving arms. By the shores lived numerous shells, often in immense beds, that now form the mussel-band of the miner; and into these seas flowed Amazonian rivers, bearing into the deep the spoils of their wooded and reedy shores. By their wide estuaries and along their banks lay extensive impassable swamps and jungles, in which gigantic reeds, calamites, and tree-ferns flourished in tropical luxuriance. Amidst these lurked fierce crocodiles and mighty lizards, which have left their footprints on the yielding mud. The whole surface of the land was covered with tall pines and tree-ferns; the seal-palm, the scale-tree, and star-leaf shot into the air in impenetrable thickets, shaking their numerous cones in the breeze, while the hum of insects sounded through their still recesses. In the distance might be seen towering snow-peaks, and here and there the smoke of the volcano, the existence of which was felt in the numerous earthquakes that shook the ground.

VI.—PERMIAN SYSTEM.

Description.—Immediately above the Carboniferous strata, we find certain strata that used to be called, as already explained, the *New Red Sandstone*, in contrast with the rocks below them, called the Old Red Sandstone. This New Red Sandstone series has been of late more thoroughly examined, and found to consist of two distinct portions, whose remains are so different that the series has been formed into two distinct systems, known as *Permian* and *Triassic*. The name Permian has been given to the system we now describe, from being developed very extensively in Perm, a province in the north-east of Russia. These rocks are found in many parts of the world, and largely in Scotland, England, Germany, and Russia. They consist of red and whitish sandstones, shales, and limestones, containing much magnesia. The rocks are remarkably variegated in colour, so much so as to be called the Variegated System; while the limestone receives the distinctive name of the Magnesian Limestone. As the old name suggests, the sandstone is of a reddish hue, and the two chief rocks, therefore, are the Red Sandstone and the Magnesian Limestone. The sandstones are used for building, as are also the limestones, which have been employed in the construction of the Houses of Parliament. Copper is also extensively obtained from one of its shales in Germany, and also lead and zinc, but not very abundantly.

Organic Remains.—The plants resemble greatly those of the Coal-measures. We find sea-weed, fine-leaved ferns, tall calamites and reeds, great pines with cones, tree-ferns, and palms like the modern fan-palm. The animal remains are not nearly so numerous as in the coal rocks. There are sponges, corals, sea-urchins, and beautiful shells. We also find fishes like those of the Coal-measures; and the Permian is remarkable as the system where the ancient form of tail, in which the spine of the fish was continued into the upper lobe of the tail, becomes almost extinct, seldom to appear again. The reptiles of this system are numerous and perfectly developed, some of them being of gigantic form. Their footprints, in particular, are remarkably abundant and large, and from these alone, the whole animal has been constructed by learned men, the truth of their drawings being proved by subsequent discovery of the entire creature. Even pouched animals, like the kangaroo, are found in the American Permian, thus shewing a gradual but slow approach to modern life forms.

Scenery of Period.—The Carboniferous Period was remarkable for the great activity of volcanic agents, but this period seems to have been comparatively tranquil in this respect. The rivers carried in their waters much iron, as they did in the Old Red Period; the seas appear to have been shallow, bearing in solution magnesia and salt, while animal and vegetable life seems scarce, as compared with other epochs. From the existence of a rough conglomerate in the west of England, it has been argued that the greater part of the period was one of glacial action, with icebergs bearing blocks and rounded débris; and if this was the case, we have a conclusive explanation of the scarcity of life during this period.

VII.—TRIASSIC SYSTEM.

Description.—The upper part of the old system, known as the New Red Sandstone, has received

[1] From Greek *krinon*, a lily.

the name *Triassic*, which means *triple*, from being found in Germany in three distinct groups, of which the first and third alone exist in Britain.

The system contains sandstones of different colours, shales, and conglomerates; but the distinguishing product is rock-salt. This occurs in beds of from seventy to one hundred feet thick in Cheshire, whence we obtain salt for daily consumption. Salt-springs also abound in salt districts, being formed by the issuing of water through the salt rocks below. The Triassic rocks are found in patches in the British Isles, but extensively on the continent of Europe and in America.

Organic Remains.—The organic remains are very scanty, especially when compared with the exuberance of life in eras before and after. Plants are rare both in number and species. We find horse-tails, calamites, and ferns. The gigantic trees of the Coal-measures no longer exist, and we have instead short palm-like trees, like the modern cycas. The vegetation is mostly of a tropical kind.

Animals are far from abundant, but are more numerous than the plants. We have no corals, and few encrinites, and bone-plated fishes are rare. There are a few shells, some crustaceans, and several great shark-like fishes. Reptiles, however, are numerous, and of gigantic size. One brute in particular, called the *Labyrinthodon*,[1] from the *labyrinth*-like structure of a section of its *teeth*, is an uncouth, frog-like creature, with great staring eyes, and immense toothed jaws. The most abundant remains in the Triassic are the great footprints of large lizards. These are found in Scotland, but are so numerous in America, that above one hundred species of creatures have been distinguished, as indicated by these footprints. Huge birds, too, were numerous, and have also left their marks upon the rocks. These rocks

Labyrinthodon.

furnish the earliest evidences of warm-blooded mammals.

Scenery.—The scenery of the old Triassic age seems to have been peculiar, and we can form but a dim notion regarding it. We can easily see that the seas were shallow, with bordering lagoons, in which the salt waters were evaporated in the strong sun-rays, and left the salt-beds that are now of such service to us. By the muddy rivers lived great crocodiles, that lurked amid the reeds and pines, and fed on shell-fish and crustaceans, and left their footprints on the yielding mud; while on the dry plains above, grew plants adapted for an arid soil and tropical climate.

[1] From Greek *labyrinthos*, a labyrinth, and *odous*, *odontos*, a tooth.

VIII.—OOLITIC OR JURASSIC SYSTEM.

Description.—We have now arrived at a remarkable epoch, whose remains, abundant and wonderful, have been more fully investigated and described by celebrated men than perhaps any other. The forms of life, habits, and scenery are more like those of our own times, and can therefore be restored with the greater certainty.

The term *Oolitic* is applied to a series of rocks

Oolitic Plants:

1, Palm; 2, Tree-fern; 3, Cycas; 4, Pandanus; 5, Zamia.

which in England form three distinct groups—the Lias, Oolite Proper, and Wealden.

The Lias is the oldest, and receives its name, a corruption of *liers* or *layers*, from the thin variegated beds of which the rocks are composed, and which present a remarkable ribbon-like appearance not easily forgotten. The Oolite[1] is above the Lias, and is so called from the rock being greatly composed of small round grains like the eggs of the cod, so that it signifies the *egg-rock*. It is also called *roe-stone* and *pea-stone*, according to the size of the particles. These strange granules consist almost entirely of lime or grains of sand coated with lime. The Wealden is the highest rock in the series, and receives its name from being developed largely in the *Weald* in Kent and Sussex. The name *Oolitic* has been applied to the whole system, because the egg-structure is common to all the rocks in the series; the term *Jurassic*, from its being largely found in Mount Jura, is also given to it.

The Oolitic system consists of a series of sandstones, limestones (sometimes so hard as to be used as marble), shales, and clays, while ironstone bands, coal, lignite, and jet are abundant. The sandstones are useful as building-stone, the celebrated Bath and Portland stones, so much used in London and the south of England, being varieties. The limestones are burned for agricultural purposes; the clays are extensively developed, and receive different names in different parts, and yield alum, sulphur, and fuller's-earth. Ironstone is abundant and good, and furnishes a great part of the iron of Yorkshire, being eleven feet thick. The coal is workable and abundant, which disproves the notion, too prevalent, that coal can be obtained only from the Coal-measures.

[1] From Greek *ôon*, an egg, and *lithos*, a stone.

Lignite is a less hard variety of coal; and the jet, which is only a crystallised coal, yields the beautiful jet of Whitby, so much used for ornaments.

Organic Remains.—The remains of plants and animals are so abundant, that their enumeration and description would fill volumes, and we can merely roughly indicate some of their wonderful forms.

Vegetable life was abundant, requiring a warm climate like that of Australia. We find seaweeds, beautiful tree-ferns, lily-like leaves, palms like the pandanus, and pines like the araucaria and yew. The clays that occur were the very soil on which those ancient forests grew, and in some of them, known as 'dirt-beds,' the roots are seen in natural position, with part of the trunk broken over, while the tree itself lies close by, as if cut down by the woodman but yesterday.

The animal remains are abundant and remarkable. We find sponges, exquisite star-corals, beautiful encrinites, sea-urchins, worms, and lobsters. The shells are very beautiful and varied, the most remarkable being the ammonite, of which there are one hundred and thirty species, and the nautilus. Gigantic cuttle-fish floated and spread their black ink through the oolitic seas. Fishes were numerous and large; huge plated sharks devoured their prey, their very names telling terrible things, such as 'strong-tooth,'[1] 'star-spine,'[2] and 'great-jaw.'[3] Tortoises also floated on the summer seas.

Ammonite.

But the most striking remains are those of reptiles, so numerous, strange, and uncouth, that the Oolite has been designated the 'Age of Reptiles.' We find enormous skeletons, some of them thirty feet long, of large lizards and crocodiles, as of the Ichthyosaurus[4] or Fish-lizard, all being more or less strange and terrible.

In these rocks, too, a most interesting discovery has lately been made, that of the earliest feathered creature—a real bird—in which the bones, claws, and full-spread plumage are finely seen. The remains of warm-blooded animals have also been found, especially of a kind of pouched creature like the kangaroo.

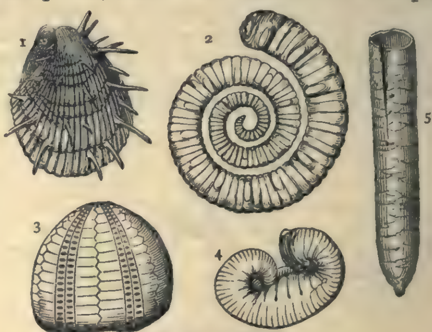
Scenery.—The scenery and animals of the Oolitic Period resemble, to a remarkable extent, those of Australia, both in vegetable and animal remains. The land and water went through many changes during this long period. In the Lias times, the seas were deep and tranquil; under the Oolite, exposed coral beaches were dashed by great breakers, that have left their work in broken shells and marls; while the Wealden seems to have been the carried deposits laid down in the estuary of a mighty river, that rolled into the sea in what is now the south of England; and the present icy lands of the arctic regions were covered with the vegetation of a warm climate, which now appears as Oolitic coal strata.

[1] *Pycnodus*, from Greek *pycnos*, strong, and *odous*, a tooth.
[2] *Asteracanthus*, from Greek *aster*, a star, and *acanthos*, a spine.
[3] *Eugnathus*, from Greek *eu*, well, and *gnathos*, a jaw or thorn.
[4] From Greek *ichthys*, a fish, and *sauros*, a lizard.

IX.—CHALK OR CRETACEOUS SYSTEM.

Immediately above the Oolite lies a system in which the chief rock is the well-known substance chalk, and which has hence received the name of the *Chalk*, or, what is the same thing, *Cretaceous*[1] System. In this system, other rocks also occur—namely, chalk-marl or blue clay, known by the local name of *Gault* or *Golt;* thick beds of green-coloured sand, called *Greensand;* and, imbedded in the chalk, nodules of flint, which, when less pure, is called *Chert;*[2] and coal, in Vancouver's Island. The chalk is used for many purposes: when it is burned, it forms a useful lime; when hard enough, is used for building-stone; and when crystallised, forms a fine white marble. The flints are an important ingredient in china, porcelain, and glass, and from the sands we obtain fuller's-earth. The whole system has been generally divided into two groups, the upper being called the Chalk, and the lower the Greensand.

Organic Remains.—The plant-remains are rare and imperfect, and seem to have been all drifted. Leaves of different kinds, palms, fruits, cones, and bits of pines have been discovered. Animal remains, however, are very numerous, and most beautifully preserved. We find sponges, corals, sea-urchins complete in form and structure, beautiful star-fish, numerous crustaceans, and varieties of the lobster tribe. The shells are plentiful, and exquisitely beautiful in form and even in colouring, and are the finest fossil preservations found in any system. They include splendid ammonites and nautiluses, and hundreds of other species, whose mere names would fill pages.



Chalk Fossils.

1, Plagiostoma spinosum; 2, Hamites intermedius; 3, Galerites albogalerus; 4, Scaphites striatus; 5, Belemnites mucronatus.

Fishes are not numerous, but are well preserved, and, as in other systems, are named from peculiarities in form or structure, such as the 'twisted-tooth,'[3] the 'wrinkle-tooth,'[4] 'thick-tooth,'[5] and such like. Reptiles are also found similar to those in the Wealden. Bones of birds have been discovered, as also bones of what seems to be a species of monkey.

Scenery.—The Chalk series appears to be

[1] From Latin *creta*, chalk.
[2] Irish *ceirthe*, stone; Welsh *cellt*, flint.
[3] *Gyrodus*, from Greek *gyros*, a twist, and *odous*, a tooth.
[4] *Ptychodus*, from Greek *ptychos*, a wrinkle, and *odous*, a tooth.
[5] *Pycnodus*, from Greek *pycnos*, thick, and *odous*, a tooth.

wholly a marine deposit. The land we know little or nothing of; sufficient, however, to shew that it was clothed with vegetable life, as in other periods, but little to picture its appearance. Over it, huge Wealden reptiles sought their prey, birds flew, and great apes swung from tree to tree. But the ocean swarmed with varied life, mild sea-breezes blew, and smiling sunbeams sparkled upon its waters; for the climate was warm, as shewn by the corals, reptiles, and monkeys. In the tepid waters lived numberless fishes and shells, and on their surface the nautilus spread its coloured sail.

The origin of chalk is a problem not yet satisfactorily settled, but the generally received opinion is, that the shores were fringed by coral reefs, which the dashing waves gradually wore down into fine powder, as they still do in tropical seas; while millions of shell-fish teemed in its waters, and left their white shells as an impalpable sand, that, under the microscope, shews the tiny houses of the old inhabitants as perfect as on the day they died. Flint seems mostly to consist of concretions round sponges, corals, and other substances. It may be found at any epoch, and occurs in many other formations besides the Chalk, though there in greatest abundance.

X.—TERTIARY SYSTEM.

We have now arrived at a new epoch in the history of the rocks, known as the Epoch of Recent Life. Henceforward, the plants and animals bear not only a close resemblance to those now existing, but a great proportion of them are identical. We discover real exogenous trees, the same corals, crustaceans, and shells, equal-lobed fishes, birds, and mammals of existing families—and all these not only more numerous than hitherto, but also more perfectly preserved. The name given to this system is a relic of the names used in early geology, when all rocks were divided into Primary, Secondary, and Tertiary. In the Tertiary System, two great periods are easily distinguishable: 1. The *Warm Period;* 2. The *Cold Period.*

1. THE WARM TERTIARY PERIOD.—This system exhibits clays, sands loose or hard, gypsum or plaster of Paris, and marls. The only true rock is limestone, made up of innumerable little shells, so numerous, that the rock is named, from its *coin*-like shells, nummulitic,[1] and is extensively found throughout the world. The limestone is burned for various purposes; the clays are extensively used; the harder sands are employed for building; and amber is also found. The strata occur exclusively in patches known as *basins*, the London and Paris basins being the most important.

Fossil Remains.—The remains are both numerous and important. Of plants there are few marine specimens, as these seem to have been too tender to be preserved. We find, however, mosses, palms, ferns, leaves, fruits, seeds of different kinds, and whole pods of pea-plants. We have real exogenous timber, with specimens of palm, cypress, and fir.

The animals resemble or are identical with existing species, and the Tertiary System has been divided into periods according to the percentage of life-remains. We have corals, star-fish of the same species as those existing, and the shells are very beautiful, finely preserved, and scarcely distinguishable from those to be gathered on our present shores.

Among the fishes, we find various species of the shark, ray, sturgeon, sword-fish; and of fresh-water kinds, the perch and the carp. Among the reptiles there are the crocodile and alligator, and the turtle. Birds are numerous, one specimen found in the Paris basin being gigantic. Mammals are found of every existing order, amongst others, the whale, elk, stag, antelope, camel, llama, tapir, hog, rhinoceros, hippopotamus, beaver, hare, squirrel, monkey, elephant, horse, tiger, and hundreds of others. So numerous are these remains in some parts, that one rock in Norfolk is known as the *Mammaliferous Crag.* But the most remarkable of the ancient animals are the huge monsters whose skeletons, carefully reconstructed, may be seen in the British Museum, some of them above 10 feet high, and 20 feet long. The most wonderful is the mammoth, with two great tusks like an elephant. Others are the *dinotherium*[1] or 'fierce beast,' the *megatherium*[2] or 'great beast,' and the *mastodon.*[3] In different parts of the world, including many places in England, remarkable caves are found filled with bones of various animals in clay or sands, known as 'bone-caves.' These caves have some of them been the dens of savage tigers and other brutes, the bones of their prey being still found; some have formed the abodes of different creatures at different times who have lived and died there; while others have had their contents washed into them by floods.

Scenery.—During this period shallow seas rolled under a genial sun, in which low islands rose crowned with palms, while the savage shark and sword-fish swam in the surrounding waters. The elephant ranged through the tall groves on shore; the hippopotamus wallowed in the fresh-water lakes; the rhinoceros crashed through rank jungles; the mastodon, mammoth, and tapir trod in forests of palm; and the wild ox and buffalo roamed over wide grassy prairies.

2. THE COLD TERTIARY PERIOD.—Immediately above the strata just described, with these strange organisms that speak of a warm climate, are found remarkable accumulations of sand, often found pure in hillocks; gravel, and clay interspersed with rounded worn boulders, known under the general title of the 'Boulder-clay,' some of the boulders being of enormous size. From various phenomena, it has been proved that the climate became arctic in character, and our country and others were enveloped from shore to shore in a vast ice-sheet, like the Greenland of to-day. From the ends of this huge ice mantle, immense masses broke off and floated away as icebergs. By and by, however, the climate became milder, and Britain looked like Norway and Iceland, with glaciers on the higher grounds, reaching here and there to the sea. Gradually the great ice-fields melted away under the rays of the genial sun, and our country looked like the present Switzerland, till at length the last glacier disappeared from the highest hills. The effects of all the wear and movement of these

1 From Latin *nummus*, a coin, and Greek *lithos*, stone.

1 From Greek *deinos*, terrible, and *thērion*, beast.
2 From Greek *megas*, great, and *thērion*, beast.
3 From Greek *mastos*, a nipple, and *odous*, *odontos*, a tooth, from nipple-like projections on its grinders.

ice-masses, whether grinding down the land or grating on the floor of the ocean, or dashing against opposing islands, are seen in the thick clay and sand deposits everywhere around us, inclosing worn stones and gravel; the scratched and rounded rock-surfaces, often bright and smooth as polished marble; the 'erratic boulders,' perched on our hill-tops and plains; and the general wavy outline of all higher ground throughout our land. This glaciation has been ascertained to extend over the whole of Northern Europe and America, and round the shores of the Antarctic Ocean.

XI.—QUATERNARY OR RECENT PERIOD.

We have now reached the last of the great geological epochs, during which sea and land, plants and animals, were much the same as they are now. This last system has been variously named the *Post-tertiary*, *Quaternary*,[1] or *Recent*.

The whole system may be divided into two chief periods:

1. *The Prehistoric*, or that before history was written.

2. *The Historic*, or that since history was written.

During the whole epoch, there is little or no solid rock, the whole deposits consisting of clay, sand, gravel, mud, peat, and the like.

Of *prehistoric* deposits, we find such remains as these: plants of all kinds, all common shells and corals, and common animals, with a few now extinct, such as the long-fronted ox, the gigantic Irish deer—a creature ten feet high to the top of its horns—the elephant, rhinoceros, hyena, bear, and mammoth, besides human remains in the shape of bones, canoes, ashes, dwellings, and weapons.

In *historical* times, we find similar remains, but the deposits are comparatively small, and the plant and animal remains are almost solely those now existing in each country. Men have left traces of themselves in buildings, coins, implements, weapons, and works of art. While peat-bogs have been formed, forests have been submerged or cut down, and considerable changes in sea-level have taken place.

Since the Glacial Period, in the Tertiary, a series of changes has been going on without intermission, accomplished by various causes and in various ways. The land has changed its level several times both by elevation and depression, the sea thus alternately encroaching on and retiring from the land. Whole countries have been gained from the ocean, such as the Fens in England and the greater part of Holland. Old beaches may be distinctly traced, with their cliffs, shores, and shells far above sea-level. Whole forests have been submerged, whose old trunks and fruits are thrown up by every storm. Huge accumulations of sand, blown or washed, have been found along its shores. Rivers have been depositing new matter under the ocean at their mouths, increasing the land by the formation of deltas, sometimes hundreds of miles in extent, laying down fine carse-land along their banks, that now forms the richest soil of the farmer, and leaving terraces far above their present level, to mark their former beds. Many lakes have been formed, others have been gradually silting up from the earthy matter brought down by rivers, while some have become dry, their beds being now waving with corn. Animals have been busy forming new islands and continents, as in the Pacific, where the coral insect leaves its skeleton to form the nucleus of future islands. Igneous agencies have been and are as active as in the olden times in changing the land and throwing out vast deposits of lava and ashes.

Man.—It is an interesting question how far back man extends into these geologic eras, and this important inquiry has of late years received great attention. Striking results have also been arrived at. It seems to be indisputably proved that man existed as far back as the great Glacial Period, at the close of the Tertiary epoch, and that he was contemporary with the hairy rhinoceros, mammoth, woolly elephants, and other gigantic creatures now long extinct, which he no doubt hunted, as he now does the fox and the deer; at which period Britain was united to France, where now the sea flows in the Strait of Dover. But this inquiry is yet in its infancy, and it would, therefore, be unwise to make positive statements where our data are insufficient. Enough has, however, been discovered to shew that in our own quiet land men lived for many ages with strange denizens, and under conditions very different from the present.

[1] From Latin *quaternus*, fourth, as coming after the Tertiary.

Rocking Stone, Fall river.

METEOROLOGY.

METEOROLOGY explains the laws which regulate weather, seasons, and climates. It involves particularly the consideration of the atmosphere—its pressure; its moisture; the alterations made upon it by heat and cold; and its electrical condition. It is by an accurate knowledge of these that we are enabled to understand the nature and causes of the incessant movements and changes going on in the air around us, and of the ever-varying appearances of the sky over our head; including the phenomena of winds and storms, of rain, dew, hail, snow, mists, and clouds, and their connections with one another, and with seasons and places.

THE ATMOSPHERE.

Its Composition—General Structure—Density—Pressure.

The atmosphere is a vast ocean of invisible gaseous matter, enveloping the terraqueous globe, and extending to a considerable height. Although it cannot be seen by the eye, it is yet felt to be an inert, material mass, which resists bodies in their motion through it, and when set in motion itself, possesses momentum or impetus, like a flying ball or a running stream. Another property of the atmosphere, which proves its genuine materiality, is its weight or pressure. It presses upon the earth, exactly as the sea does, under the influence of gravitation. At the sea-level, the average pressure is $14\frac{2}{3}$ pounds on every square inch; it is nearly the same as the pressure of a lake of water 33 feet deep, or a lake of mercury $2\frac{1}{2}$ feet deep. The construction of the barometer, or instrument for constantly measuring this weight, and shewing the degrees of its fluctuation from day to day, is explained under PNEUMATICS.

The fluid of which the atmosphere consists, is found to be not a single substance, but a mixture of several substances, totally distinct in their properties, and serving quite different offices in the economy of nature. The two chief ingredients—nitrogen and oxygen—which make up more than $\frac{99}{100}$ths of the whole mass, are as different in their character as water and alcohol. The proportions of these two are very nearly 77 of nitrogen to 23 of oxygen by weight. The nitrogen is therefore the principal element in point of quantity; but the oxygen performs the greatest variety of functions: it is the supporter of life, and the indispensable agent in combustion, in putrefaction, and in many other natural processes.

Deferring in the meantime the consideration of the other ingredients of the atmosphere, we have to study in the first place the mode of mixture of these two gases, and the general structure of the mass they compose. Although the mechanism and constitution of a gas are not apparent to our senses, yet we can infer with certainty that it is made up of atoms or molecules which keep one another at a distance by a repulsive force. From the fact that any gas can be compressed into a very small fraction of its ordinary bulk, we are sure that its particles are usually at a great distance from each other in comparison with their size. Now, suppose two flasks connected by a tube having a stop-cock, by which communication can be cut off, and suppose the one filled with nitrogen, and the other empty; on turning the stop-cock, part of the nitrogen will rush into the empty flask until it is equally spread over the whole space; for there is no stable balance of the repulsion if a particle is nearer its neighbour on one side than on the other. This uniform diffusion takes place almost instantaneously when the one flask is empty. But now, suppose both filled, the one with nitrogen, and the other with oxygen; when the communication is opened, each gas spreads itself uniformly through the whole space of both flasks, precisely as the nitrogen alone did, only in this case time is required. The gases mutually interpenetrate, and the molecules of the one retard the progress of those of the other, but do not otherwise affect the ultimate result. Each gas is independent, and distributes itself, and exerts its pressure precisely as if the other were not there. It is owing to this important principle that the proportion of oxygen to nitrogen is the same in all parts of the world and at all heights. The same law of uniform diffusion, and independence of the presence of other gases, holds with regard to the carbonic acid gas and the aqueous vapour existing in the atmosphere, although, in the case of aqueous vapour, its constant liability to condensation prevents its ever attaining to a state of actual uniformity.

Taking the entire mass of the atmosphere, considered as an ocean of gaseous or elastic fluid, its density must diminish as we ascend from the earth. The rate at which the density of the air diminishes upward, and the estimation of its entire height, are complicated by the decrease of temperature that is found to take place as we ascend (see page 41). It may be stated here, in a general way, that one-half of its material mass lies within three miles from the earth, and three-fourths of it within less than six miles. From the observation of luminous meteors, it is inferred that it is at least one hundred miles high, and that, in an extremely attenuated form, it may even reach two hundred miles.

MOVEMENTS OF THE ATMOSPHERE.

All the movements and changes to which the air is subject, originate, some way or other, in the unequal distribution of heat.

If two adjoining spots of ground are of unequal temperature, and communicate an unequal temperature to the columns of air lying upon them, the column which is most heated will be expanded, so as to overtop the other, and will also be made rarer or lighter. Two effects will arise from this: a lateral or horizontal movement of the air from the cold to the warm column will take place *below*, according to the general law of hydrostatics, that a heavy fluid buoys up a light one. But if we consider the condition of the two columns *above*, or at their upper ends, we will find that the

opposite effect must arise. Not only will the uppermost portion of the long column, which rises to a point where the short column has ended, and has therefore nothing but a vacuum to flow to, have a side-movement towards the other, but portions far beneath the top will have a pressure so much greater than the contiguous portions of the shorter column, that they too will flow out laterally, and determine a current tending to equalise the difference of heights and pressures.

When a difference of temperature exists between two spots that lie near one another, the effect of the aërial currents which take place between them is to equalise the temperature. Its lateral currents are the effect of unequal heating, and in some measure the remedy. These lateral currents are felt and recognised by us under the name of *winds*. If the differences of warmth that originate them were only limited and temporary, the carrying of heat to and fro would bring about an equality, and then the air would come to a perfect repose; but these differences of warmth are perpetually kept up; hence the lateral currents go on for ever without ceasing. The middle band of the earth, or the equatorial zone, is exposed to the burning radiance of a direct sun, while the two polar regions are so faintly heated, that snow never melts upon them; and this great standing inequality keeps up two grand sets of movements, which encompass the globe. The equatorial air, being warmer and lighter below than the air on each side, is buoyed up by the cold masses moving in upon it from north and south, and thus two great under-currents are maintained between the poles and the equator. The equatorial mass being expanded far upwards, overtops and overpresses the upper portions of the colder columns on each side, and therefore flows in upon them on both sides; thus causing two great upper-currents towards the poles, while the under-currents are moving from the poles. The inequality of the equatorial and polar regions in respect of heat is thus in some degree mitigated; but it is by far too great to be entirely done away.

We have supposed, for simplicity's sake, that the atmosphere is divided into an equatorial and two polar masses; but in reality there is a constant gradation from the equator to the polar regions, and the movements will take place between every two adjoining portions of atmosphere of which one is farther north or south than the other.

Although, as a general rule, the temperature of the earth decreases from the equator to the poles, this is not strictly or at all times true. Various causes occur to render a high latitude as warm as, or warmer than a lower, and in such a case a contradiction will arise to the general movement, which will have peculiar local consequences.

VAPOUR OF THE ATMOSPHERE.

Vaporisation—Dew—Mist—Clouds—Rain—Hail—Snow.

Next in quantity to nitrogen and oxygen, although very small compared with these, is the vapour of the atmosphere; that is to say, the gaseous water or steam that is constantly present in it. Although comparatively small in amount, this ingredient of the atmosphere is of immense importance in its effects. Unlike the other gases, it is easily reduced from the aërial to the liquid form, or to water as we usually find it; and it is constantly going through the processes of becoming liquid and descending to the earth, and again rising into the air in the gaseous or invisible form. The great agency connected with these transformations is heat. When water passes into steam, it takes in a large amount of heat, which is rendered insensible to the feeling or to the thermometer; and when steam or invisible vapour is condensed into water, all this heat is given out again (see NATURAL PHILOSOPHY).

It is essential to bear in mind that true gaseous water, steam, or elastic vapour of water, which all mean the same thing, is invisible, like the other portions of the atmosphere; and that the white cloud that appears at the chimneys of steam-boats and locomotives, and at the spout of a kettle, is not gas or elastic vapour, but vapour partially condensed, whose particles only require to be brought together to become drops of water. It is, in fact, water in the form of something like dust. Mist, fogs, and clouds are of the same character: they are not gaseous steam, but precipitated watery particles destitute both of mutual repulsion and of the latent heat of steam. When the atmosphere contains nothing but true steam, it is transparent and cloudless.

The formation of steam out of water is most conspicuous in the process of boiling, where the surface is kept in an intense bubbling state, each bubble containing a mass of steam, which forces its way up into the air. This boiling takes place at 212° of the thermometer, called for that reason *the boiling-point*. The steam thus formed has an elastic force equal to the pressure of the atmosphere, or a force of $14\frac{2}{3}$ pounds to the square inch. The reason for the *violent* escape of steam at 212° is, that it has attained a force equal to the weight of the atmosphere pressing on the water, and is therefore able to set aside this pressure, or make its way in spite of it. But even at temperatures below boiling, water passes into steam slowly and invisibly. It is well known that a wet surface soon becomes dry; in other words, that the water upon it disappears. Water, however, cannot be annihilated; in the drying process, the liquid water becomes gaseous invisible water or steam, and mixes with the other steam contained in the air.

The rapidity of the process of drying up, or of the passing of water into steam, depends, in the first place, on the temperature of the water. We have seen that it is abundant and violent at 212°; and it is less and less for every degree downwards. The elastic force of the steam produced also depends upon the temperature. The elastic force of steam at the boiling-point is equal to the pressure of the atmosphere; while the elastic force of steam produced silently at 80° is only $\frac{1}{30}$th of the elasticity of the atmosphere, or equal to one inch of the barometer.

Now, the entire quantity of steam that can rise is limited by the temperature in the same manner as the elasticity is limited. Water at 80° will give forth vapour, until as much has been produced in the atmosphere as would counterbalance one inch of mercury; evaporation then ceases, and the air is said to be *saturated* with steam. Whether the steam rise freely into the atmosphere, or rise into a vacuum, no more will be produced at 80° than this quantity. If the temperature were raised to

90°, there would be the means of supporting an additional quantity of steam, and evaporation would again go on, until as much were distributed through the air as of itself would counterbalance 1·36 inches of mercury, or about $\frac{1}{22}$d of the weight of the whole atmosphere. With every new addition of heat, new evaporation would go on, which would be of the silent kind up to 212°, when the full pressure of the atmosphere would be reached. But as the water on the earth's surface does not rise much above 80° even at the equator, and is far below this temperature in other regions, the whole weight of vapour in the air rarely amounts to one inch of mercury; so that, if the pressure due to nitrogen and oxygen by themselves were 29½ inches, the whole pressure, including the vapour, would be only about 30 inches, and at the utmost 30½ inches.

It has been stated, that at 80° vapour rises till as much exists in the air as weighs an inch of mercury; and that if the heat be increased, an additional quantity can be produced and supported. Let us now consider what must happen if the air were saturated with all that could be maintained at 80°, and if the temperature were then lowered, say to 60°. While at 80°, the vapour may amount to an inch; at 60°, it amounts only to ·52, or little more than half an inch. If, therefore, the full quantity which can subsist at the higher temperature has been produced, and if the temperature then descend to the lower point, there will be nearly half an inch too much for the reduced temperature, and this excess will be thrown out in the state of visible non-elastic vapour, or fall down as liquid drops. There will be either some kind of fog, cloud, or mist, or the aggregation of these into watery coherence.

Tables have been formed, the result of accurate experiment, shewing the elasticity of the vapour that can be maintained at each degree of Fahrenheit, from 0° to 90°, expressed in inches of barometric pressure.

If less steam is formed than could be supported at the temperature, there is said to be a certain amount of *dryness* or *thirstiness* in the air; meaning that there is room for further evaporation.

If the quantity of vapour in the air is less than what is supportable at the temperature for the time being, there is some lower temperature which this quantity would completely saturate. Such temperature is called the temperature of the *dew-point*. The dew-point is the lowest point to which the air can be cooled down without giving out visible moisture. If the air were saturated, the temperature and the dew-point would be the same; if the air is dry, or not saturated, the dew-point temperature is below the air temperature; and the difference between the dew-point and the temperature of the air is a measure of the dryness.

The number of degrees of Fahrenheit between the air temperature and the dew-point temperature is not, however, the exact estimate of the dryness, as will be seen from the following example. Suppose the temperature of the air 80°, and the dew-point 70°, then the amount of additional vapour that could be supported would be found thus:

Vapour sustainable at	80°,	1·001 inches.
" "	70°,	·727 inch.
Difference, . . .		·274, above 1-4th of inch.

Thus a difference of 10° of temperature makes a vacancy for a fourth of an inch of vapour. Take now a difference of 10° farther down in the scale. Suppose the air 40°, and the dew-point 30°:

Vapour sustainable at	40°,	·264 inch.
" "	30°,	·186 "
Difference, . . .		·078, about 1-12th of inch.

So that a difference of 10° between 70° and 80° makes a dryness or deficiency three times as great as a difference of 10° between 30° and 40°. Water would disappear three times as fast in the one case as in the other.

As the mercurial column expresses only the pressure of the sum-total of the atmosphere, some other means must be adopted for finding the amount of vapour by itself. Instruments used for this end are called *hygrometers;* from the Greek *hygros*, moist, and *metron*, a measure.

Apart from instruments, we judge of the dryness of the air, or of the additional amount of vapour which it could sustain, by the time required to dry wet bodies, such as the ground, or wet clothes hung in the air.

The chief instruments for determining with accuracy the dryness of the air, and the actual amount of aqueous vapour that it contains—technically its *hygrometric condition*—are Daniell's hygrometer, and the wet-and-dry-bulb thermometers.

The principle of Daniell's hygrometer is to cool the air down upon some surface till dew appear, and to mark the temperature when this happens. Thus, suppose a tumbler standing in the open air is cooled by pouring in cold water, or any other cold liquid, until the sides of the tumbler are covered with dew, the temperature of the glass at the moment that the dewing begins will be the temperature of the dew-point. In the actual instrument, the cooling is produced by the rapid evaporation of ether. But as the process of observation is rather delicate, and attended with trouble and expense, the wet-and-dry-bulb thermometers have come into more general use.

The determination of the dew-point by the wet-and-dry-bulb thermometers depends on the effect of evaporation in causing cold. When water passes into invisible vapour or steam, it absorbs from whatever substances it touches a large amount of heat, and the more intense the evaporation, the greater will the cooling be. In applying this principle to measure the humidity contained in the air, two thermometers are taken—one of the ordinary construction, which serves simply to give the temperature of the air; and the other having its bulb covered with a piece of rag, which is kept constantly wet by communicating with a cup of water by an absorbent wick. The water round the bulb will be constantly evaporating when there is any dryness in the air; and the greater the dryness, the more intense the evaporation, and consequently the greater the cooling of the bulb. Hence this moist-bulb thermometer will fall in proportion to the dryness of the air at the time. We have therefore only to compare the two thermometers—the one giving the air's temperature, and the other a reduced temperature depending on the rate of evaporation or the degree of thirstiness—in order to judge of the comparative quantity of moisture existing in the surrounding atmosphere. Tables

are used along with this hygrometer for calculating the dew-point temperature, which is ascertained, without calculation, by Daniell's instrument.*

The force of evaporation, or the quantity of water which is converted into invisible vapour in a given time, depends upon the dryness of the air, and upon its stillness or motion. The effect of a current of air is to carry off the vapour from the surface as it rises, and leave the space free for an additional supply. The more rapid the wind, the faster every wet surface dries up.

Clouds.—We must now consider more particularly the peculiar forms of visible vapour. Mist, fog, and cloud are names for nearly the same thing. When there is a general haze of precipitated vapour covering the whole sky, and coming down to the surface of the earth, it is termed a *fog*. When a white smoke is seen to rise from the courses of rivers and wet land, it is called a *mist;* but mist and fog are often indiscriminately applied to the same appearance —namely, to a vapoury haze lying upon the ground. *Clouds* are the masses of haze or fog which are seen floating in the higher regions, and which do not descend to the ground.

The steam of a kettle when it becomes visible, the white cloud of a steam-chimney, our breath in a moist or cold day, are all precipitated moisture or mist. Sometimes this mist is rapidly reabsorbed as it spreads out, shewing that there is a certain dryness or vacancy in the air sufficient to take it in among the invisible steam, when it is distributed over a somewhat larger surface.

If the air is exposed to a cooling, so as to bring it beneath the temperature of the dew-point, vapour must be thrown out everywhere, and a fog or mist will be formed. In this manner are formed the dense fogs of the polar seas, the fogs found along the courses of rivers, upon the sides of mountains, and over shoals and headlands. The celebrated fogs of London originate in the same way; but their black and thick appearance is owing to the quantity of smoke which is suspended in them.

The formation of clouds, as well as their frequent disappearance, can, in most cases, be readily explained by the general principles regarding the atmosphere and its vapour already laid down. Thus, we often see a clear morning gradually become overcast with clouds. This arises from the sun's rays heating the earth, and causing currents of warm, moist air to ascend into regions where it is cooled by expansion below the dew-point, and part of its vapour is condensed into clouds. As the day declines, the process is reversed; the cloudy particles descend and are dissolved, and a cloudless evening ensues.

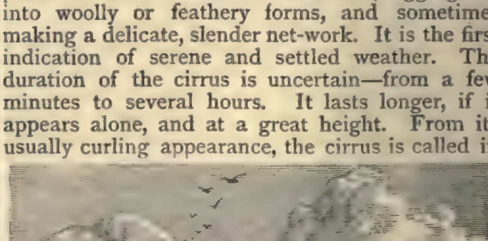
It is not uncommon to see the top of a hill wrapped in a stationary mist or cloud, even while a pretty rapid breeze is blowing over it. The explanation is simple. The current of air, in crossing the hill, rises into a region where the temperature is below its dew-point, and part of its vapour is there condensed into mist; but, as it descends the other side, it becomes warmer, and can again dissolve the watery particles. The substance of the cloud is thus really in motion over the summit; but it is constantly being shorn off on the lee-side, and as constantly receiving additions on the other side, so that it appears motionless as a whole.

A question often asked regarding clouds is thus answered by Mr Buchan in his valuable *Handy Book of Meteorology:* 'A very natural inquiry is: How are clouds suspended in the air? The example of a cloud appearing to rest on the top of a hill though a strong wind be blowing at the time, suggests an explanation. The cloud itself may appear stationary or suspended, but the particles of which it is composed are undergoing constant renewal or change. The particles are upheld by the force of the ascending current in which they are formed; but when that current ceases to rise, or when they become separated from it, they begin to fall through the air by their own weight, till they melt away and are dissolved in the higher temperature into which they fall. Hence, as Espy has reasoned, *every cloud is either a forming cloud or a dissolving cloud.* While it is connected with an ascending current, it increases in size, is dense at the top, and well defined in its outlines; but when the ascending current ceases, the cloud diminishes in size and density.'

The classification of clouds proposed by Luke Howard in 1803, is still universally followed. The three principal forms are the *cirrus*, or feather-cloud, the *cumulus*, or heaped-cloud, and the *stratus*, or stretched-cloud. The *cirrus* is com-

Cirrus.

posed of thin threads or filaments, aggregated into woolly or feathery forms, and sometimes making a delicate, slender net-work. It is the first indication of serene and settled weather. The duration of the cirrus is uncertain—from a few minutes to several hours. It lasts longer, if it appears alone, and at a great height. From its usually curling appearance, the cirrus is called in

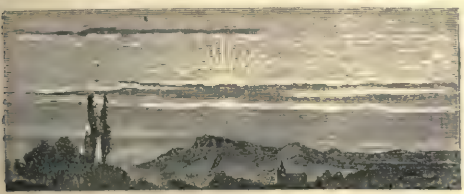


Cumulus.

England the *mare's-tail* cloud. The *cumulus* is the kind of cloud resembling mountains piled upon mountains, and generally ends above in rounded

* Besides the above, there are various instruments called *hygrometers*, depending on the principle of the shrinking and expanding of bodies in relation to the degree of humidity with which they are affected. Fibrous vegetable substances, such as ropes, contract by imbibing moisture; while, on the contrary, hairs and catgut (strings of violins) contract by drought. Hair has been found to be the most delicate in hygrometrical motions. Saussure accomplished the construction of a hygrometer from a single long hair, previously cleaned in a soda lye. Various philosophical toys, as ornaments for mantel-pieces, have also been constructed to indicate the dryness and moistness of the atmosphere, all on the similar principle of contraction and expansion of a hair, piece of catgut, or part of the beard of the wild oat.

masses, while it is horizontal below. The appearance, increase, and evanishing of cumulus, in fine weather, are often periodical, and correspondent to the degree of heat. Generally, it forms a few hours after sunrise, attains its highest degree in the hottest hours of the afternoon, and decreases and vanishes at sunset. If the upper region, with its drying power, predominates, the upper parts of the cumulus become cirrus; but if the lower region predominates, the basis of the cumulus sinks, and the cloud becomes *stratus*, which appears as a



Stratus.

long horizontal band of moderate density, with its lower surface resting upon the earth or the water. Combinations of the above forms have been discriminated under the names of *cirro-cumulus*, *cirro-stratus*, and *cumulo-stratus*. The black rain-cloud, which seems a general mixture and confusion of all the clouds in the heavens, has been called the *cumulo-cirro-stratus* or *nimbus*.

The *cirrus* clouds are the most elevated; and must be often made up of snow-particles, for even under the equator, water would be frozen at such a height. In general, we may say of the light fleecy masses that we see on a summer-day, that they are made up of snow-powder or frozen particles. The *cirro-cumulus* is formed from the cirrus by the fibres breaking and collapsing into small roundish masses. It is this which is known as a mackerel sky, and is attendant on dry and warm weather. The *cirro-stratus* clouds consist of horizontal masses, dense in the middle and thinned towards the edges, so that a group of them resemble a shoal of fishes. Their prevalence indicates a coming storm.

The *cumulus* clouds are evidently the precipitation of the ascending vapour in the cold upper regions; for they generally increase with the heat of the day, which disperses all superficial mists. The *stratus*, on the other hand, has more the character of a night-cloud: it is a result of the cooling of the air in the evening, and comes out in the lower regions of the atmosphere. All mists and fogs are of this species of cloud; which, in its lightest state, does not wet leaves or any objects with which it comes in contact. Sometimes it remains quiet, and accumulates in layers, till the atmosphere is incapable of sustaining its weight, when it assumes the condition of the heavy and dark *nimbus*, and falls in a shower of rain.

The extreme height to which clouds may reach has never been accurately determined; but from observations made in balloon ascents, it is probable that the cirrus cloud is often ten miles above the earth.

The average amount of the sky covered by clouds, is an important element in the climate of a country. It is usually measured by the scale of 0 to 10; 5 indicating that the sky is half-covered, 10 that it is wholly obscured. In Shetland, three-fourths of the sky is the average space covered with cloud; the mean for the whole of Scotland is less than two-thirds, being 6·7 in the west, and 6 in the east and interior.

Dew.—When moisture is precipitated at night in the form of wetness, and drops on the surface of the ground and on the leaves of plants, it receives the name of *dew*. This precipitation arises when the surface of any body is cooled below the dew-point temperature of the air at the time. Thus, if the dew-point were 45°, and if by any means a glass tumbler were cooled down to 40°, the film of air lying next to it would also be cooled down to 40°, and would therefore have to give out all the vapour which it could not hold at that temperature; but the precipitated surplus in this case would not appear as mist in the air, but would adhere to the surface of the glass. When cold glasses are brought into a warm room, they sometimes become dewed all over in this way. The bringing out of visible dew is, as we have seen, the means of determining the dew-point temperature in Daniell's hygrometer.

Night-dews are most copious when the sky is clear. The reason of this is, that the earth cools faster under a clear sky than when hung over with dense clouds, which prevent the radiation of the heat; just as bed-curtains make a bed warmer. Wind also prevents the deposition of dew; because the air in contact with the earth is constantly changed, so that the temperature does not fall sufficiently low. The surfaces which naturally radiate off their heat with most rapidity are the first to sink below the dew-point temperature and to become dewed. Thus, rough surfaces are wetted sooner than smooth, plants sooner than glass, and glass sooner than metals. Metals being good conductors of heat, as fast as their surface cools, heat flows to it from the interior, and consequently the temperature of the surface cannot sink till the whole mass throughout has parted with its heat. Woolly and fibrous substances cool very fast at the surface, and are therefore rapidly bedewed. No dew can fall on a surface till its temperature has fallen below the dew-point; hence, in the case of a very dry atmosphere, there may be no dew formed at the coldest time of the night. In arid deserts, and in the countries where dry winds prevail, dew is not often seen.

When the surface dewed is below the freezing temperature, the vapour is not only precipitated, but is also frozen; hence the origin of *hoar-frost*, or frozen night-dew. The occurrence of hoar-frost is a proof that the temperature of the ground has fallen below 32°, as well as below the dew-point temperature. As in the case of dew, everything that prevents the radiation of heat arrests the formation of hoar-frost. During the chilly nights of spring, plants that are sheltered by trees are less liable to be frozen than those which are fully exposed; and a slight covering of straw, or even of paper or netting, will often afford an effectual protection. Vineyards, it is said, have frequently been saved from the effects of frost by enveloping them during the night in a cloud of smoke.

Rain is the aggregation of the cloudy particles into masses or drops. The causes of the formation of clouds have been already explained. Every cloud does not end in rain; it is only when the whole mass of air between the cloud and the earth is saturated, that the watery particles fall down.

Snow.—When the temperature of the stratum of air from which the rain falls is under 32°, the

vapour or clouds must necessarily be frozen, and the descending particles will be *snow* instead of rain. Snow-flakes are the aggregation or union of frozen particles, just as rain-drops are the union of watery particles. They aggregate, according to the law of the crystallisation of water, into regular and symmetrical forms, of which the general character is a six-sided figure; as, for example, six needles branching from a centre, or six arms from a six-sided nucleus, each needle being three or six sided. Though single crystals always unite at angles of 30°, 60°, or 120°, they nevertheless form, by their different modes of union, about 1000 distinct

varieties of snow-flake, some of which are figured in the preceding engravings. Any agitation of the air, or an increase of moisture or temperature, destroys, of course, their delicate and beautiful structure.

Hard pieces of ice falling in showers are called *hail*. The mode of their formation is not clearly understood. The sudden ascent of moist air into the upper regions, where it encounters a cold current, is probably the common cause of hail. Hailstones vary in shape, and when cut across are found to be composed of alternate layers of clear and opaque ice, enveloping a white nucleus. Many of them seem to be agglomerations of several hailstones. They vary in size from the smallest shot to several inches in diameter.

Besides *nitrogen*, *oxygen*, and *watery vapour*, the atmosphere contains minute quantities of numerous other substances—carbonic acid, ammonia, ozone, exhalations of all kinds, dust, seeds or germs of plants and animalcules, &c. But, however important some of them may be in the economy of nature, the consideration of them does not properly belong to meteorology.

SURFACE OF THE EARTH IN RELATION TO THE ATMOSPHERE.

Mean Temperature—Trade-winds—Sea and Land Breezes—Hygrometric Changes—Fall of Rain—Fluctuations of the Barometer and Thermometer.

The changes and fluctuations of the atmosphere have all a relation to the peculiarities of the earth's surface, and especially to the unequal heating of its different parts, owing to the varied action of the sun, the distribution of sea and land, and the different elevations of the land.

By the *mean temperature* of a place is understood the average temperature for a whole year, or for a number of years. If observations were made of the temperature for every hour in the course of a day, the average of all these would be the mean temperature of the day; also the mean of the greatest and least temperatures would be pretty nearly the mean of the day. If the mean temperatures of 365 days are found in this way, and an average taken of the whole, this gives the average or mean temperature of the year. And if a great many years have been observed in the same manner, the average of the whole would be reckoned the general mean temperature of the place where the observations have been made.

The action of the sun is the chief source of the warmth possessed by the atmosphere and the ground, though not the only source (see GEOLOGY and PHYSICAL GEOGRAPHY).

The reason why the sun heats the equator and the regions adjoining more strongly than it heats the temperate and polar regions, is, that at the equator it rises higher in the heavens, and shines more directly downwards. The farther away a place is from the equator, the less is the average noonday height of the sun, and therefore the smaller the influence it exerts.

The mean temperature of the equator is about 80°. If the whole earth were a perfectly smooth globe of one uniform kind of surface—that is, if it were all sea, or all one kind of level land—the temperature would decrease steadily from the equatorial amount, according to the latitude; but the variations of the surface cause many important deviations.

The whole force of the sun's rays does not act directly on the solid surface of the earth; the atmosphere, especially when charged with vapour, arrests a certain portion of the heat, and is itself rendered warm by the portion arrested. This is one source of the warmth of the air. When clouds are spread out in the atmosphere, the resistance to the rays is still further increased, and a greater portion taken up by the air itself. The other sources of atmospheric heat are, contact with the surface of the earth, and the radiation of heat from the ground upwards.

The air exercises a very important influence in keeping up the mean temperature of the earth, by resisting the passage of heat outwards, on the same principle that our bodies are kept warm by clothing. The thinner the covering of air, the colder would the earth be; as we see in ascending to the tops of mountains, at which the temperature is always much lower than at the sea-level—the cold increasing with the height. These high places receive a more intense solar radiation through the thin covering of air that lies upon them; but such is the ease with which the heat can radiate off through a thin atmosphere, that they are always kept comparatively cold. If we had no atmosphere at all, the rays of the sun would be very intense where they actually struck, but so rapid would be the loss of heat by radiation, that the whole earth would be permanently kept far below freezing; no liquid material of any known kind could exist on its surface.

Trade-winds.—The first great effect on the atmosphere of the unequal temperature of the different parts of the earth, and especially of the steady decrease of heat from the equator to the poles, is to produce the two grand currents which we have already described: an upper-current from the equator to the poles, and an under-current from the poles to the equator. If the earth were at rest, these currents would blow exactly north and south, but the daily revolution of the globe has an effect in altering their directions. The equator, or thickest portion of the earth's body, considered as a ball revolving on an axis, moves with the greatest rapidity in the daily whirl; any place upon it is carried round at the rate of upwards of 1000 miles an hour. But the belts on each side of the equator being smaller in circumference, any point on one of them is moved with proportionably less rapidity. Thus the belt or zone at 60° of latitude has only half the circumference of the equatorial zone; so that a place upon it will move round only 500 miles an hour. Now the atmosphere revolves along with the earth, and every portion of it will have the same velocity as the place on which it lies. But if the equatorial air, with its high velocity, is carried away in the upper-current to a place with a lower velocity, the air will still persevere in its equatorial speed, and will consequently outrun the speed of the place upon which it has come, and be felt as a strong wind in the direction of the rotation.

A similar explanation serves to shew that the under-currents from the poles to the equator will not be due north and south, but will have, in addition, a direction towards the west.

According to this simple theory, the prevailing winds ought everywhere on the earth's surface to be easterly: in the northern hemisphere, they should blow from the north-east; in the southern hemisphere, from the south-east. And at sea within the tropics, and to some distance beyond them, this is in fact the case. The great polar currents are there known by the name of the *trade-winds*, because they are so constant that they can be calculated on by navigators. The trade-winds begin to be felt at about 30° of latitude on each side of the equator. Ships entering upon this belt begin to feel a steady easterly breeze, which continues, although with some variation, to within 2° of the equator. The two currents from north and south meet about the equator, and completely neutralise each other; and their meeting forms a belt varying from 150 to 550 miles in width, called the *region of calms and variables*. There is no steady wind in this region; its atmosphere is generally calm, having at certain seasons light southerly winds, interrupted by fearful storms and tornadoes.

Beyond the region of the trade-winds, the prevailing currents are in the opposite direction—in the northern hemisphere, for instance, from the south-west. To account for this, we must suppose that the two great currents change places, and that about the latitude of 30° the upper equatorial current descends to the surface of the earth.

The region of the south-east trade-winds is much larger than that of the north-east, the belt between them lying generally not at the equator, but several degrees north of it. The entire belt of the trades shifts in some degree northwards in summer, and southwards in winter, following the course of the sun.

Direct proofs have been furnished that in the regions of the trade-winds there are upper return-currents flowing in the contrary direction. The ashes of the volcano of St Vincent, on one occasion, were carried from west to east, to the astonishment of the inhabitants of Barbadoes, who were experiencing at the time the easterly wind.

Sea and Land Breezes.—The great polar and equatorial currents are modified by another class of currents, of a more local character, arising from the unequal susceptibility of the sea and the land to the sun's heat. If the sun shine with the same directness and force on two tracts of surface, the one water, and the other solid ground, the ground will be most rapidly heated, and at the end of the day it will be found much warmer than the water. On the other hand, in the absence of the sun, the land cools fastest, and at the end of the night it will be found below the temperature of the adjoining water. This difference causes an inequality in the temperature of the columns of air lying upon the two surfaces. When the land is hottest, the air resting upon it will be hotter and lighter than the air over the sea; hence the cold air from the sea will rush in upon the hot. Thus during the day, when the land is warmer than the sea, there will be a breeze from the sea to the land, and during the night, a breeze from the land to the sea. These *sea and land breezes* are felt regularly on all the sea-coasts when not overborne by other winds.

Monsoons.—Where a large tract of land joins a great expanse of sea, as on the coasts of America and the south of Asia, the sea and land breezes become very considerable. The easterly trade-winds are often reversed by them. But the most powerful effect of the sea and land winds is annual, or dependent on the seasons. The most remarkable example of this is furnished by what are called the *monsoons*—from the Arabic word *mausim*, a set time or season—experienced along the coasts of Africa, India, and China. When the sun is far north in midsummer, and shines with direct rays on the Asiatic peninsulas, the land in them is rendered very much hotter, both day and night, than the ocean, and a strong sea-wind sets in towards these coasts from the south-west—that is, in a direction opposite to the great current that causes the trade-winds. Hence an immense wide-spreading conflict arises, which begins about the month of April, or two months before the sun has reached his extreme north declination. The beginning of the conflict in April causes furious rain, wind, and thunder-storms; but in the course of two or three weeks the sea-breeze completely overcomes and suspends the trade-wind, and continues steadily to prevail from April to October; this is called the *south-west monsoon;* and it can be as much calculated on for navigation as the trade-winds in their most uninterrupted regions. The influence which sustains this wind becomes gradually weaker as the sun moves southward, and in October it becomes too weak to overcome the trade-wind, and the two meeting with equal force, cause a second violent tumult of rain and storms, till in a short time the trade-wind prevails; which then continues during the winter half-year, and forms what is called the *north-east monsoon.*

In the Atlantic, a similar action is perceived. In the summer-time, the land of North Africa is made so much hotter than the adjoining sea, that

a brisk south-west or south-south-west wind blows between the equator and the southern limit of the northern trade, which is then at about 10° or 12° north latitude. In America, also, similar breezes are experienced.

*Rainfall.**—The chief sources of evaporation are the seas, lakes, and rivers. Although there is three times as much sea as land, this is not more than enough to keep up a sufficient moisture for the habitable countries; for although some regions have rather more than is desirable, many large tracts of country remain desert and uninhabitable solely from the dryness of their air and the scarcity of rain.

The evaporation is necessarily greatest in the equatorial regions, where the temperature is greatest, and decreases steadily towards the poles. And although a great deal of the tropical evaporation is transported by air-currents into higher latitudes, the precipitation of vapour, or the rain, is also most abundant in the warmest climates, and in the neighbourhood of the tropical seas.

Rain is the most capricious of all the meteorological phenomena, both as regards its frequency and the amount which falls in a given time. It rarely or never falls in certain places, which are, on this account, designated the rainless regions of the globe—the coast of Peru, in South America; the great valleys of the rivers Columbia and Colorado, in North America; Sahara, in Africa; and the Desert of Gobi, in Asia, are examples; whilst, on the other hand, in such places as Patagonia, it rains almost every day. Again, the quantities which have been recorded at some places to have fallen at one time, are truly enormous. In Great Britain generally, if an inch fall in a day, it is considered a very heavy rain. In many parts of the Highlands of Scotland, three inches not unfrequently fall in one day. On the 5th of December 1863, there fell at Portree, in Skye, $12\frac{1}{2}$ inches in 13 hours. At Seathwaite, in Borrowdale, 6·62 inches fell on November 27, 1845. But it is in continental, and especially tropical countries where the heaviest single showers have been recorded. The following are a few of the most remarkable: At Joyeuse, in France, 31·17 inches fell in 22 hours; at Geneva, 30 inches in 24 hours; at Gibraltar, 33 inches in 26 hours; on the hills above Bombay, 24 inches in one night; and on the Khasia Hills, 30 inches on each of five successive days.

The heaviest annual rainfall on the globe is 600 inches on the Khasia Hills, about 500 inches of which falls in seven months during the south-west monsoons. This astonishing amount is due to the abruptness of the mountains which face the Bay of Bengal, from which they are separated by 200 miles of low swamps and marshes.

The following are some of the annual rainfalls in the tropics: Singapore, 97 inches; St Benoit (Isle of Bourbon), 163 inches; Sierra Leone, 87 inches; Caracas, 155 inches; Pernambuco, 106 inches; Rio Janeiro, 59 inches; Georgetown, 100 inches; Bahamas, 52 inches; and Vera Cruz, 183 inches.

In general, *when a mountain-chain crosses the course of an ocean wind, the weather-side is wet and the lee-side is dry.* The trade-winds of the Atlantic sweeping over the continent of South America become cooled as they ascend towards the Andes, and, depositing their vapour, feed the mighty streams of the Amazon and Orinoco. On the west side of the wall of the Andes, in Peru, rain is almost unknown.

Distribution of Atmospheric Pressure.—The varying pressure of the atmosphere, from place to place and from time to time, is the chief cause of all fluctuations of wind and weather. A knowledge, therefore, of the distribution of this pressure over the globe, and the laws of its changes, as indicated by the barometer, is the basis of meteorology. *Variations* of the barometer are of two kinds—periodical and irregular. Of the regularly recurring variations, the *daily* variation is of small amount, and of little direct importance. The phenomenon has its cause in the daily march of the sun round the globe. The *annual* variation follows the march of the sun from one side of the equator to the other. The greater power of the sun in the northern hemisphere in summer rarefies the air, and causes a transference of a part of it into the colder southern regions, thus diminishing the pressure. The presence of a greater proportion of vapour acts in the same direction, owing to vapour having less specific gravity than dry air. As a rule, then, the atmospheric pressure is least in the summer, and greatest in the winter, in each hemisphere. But this annual fluctuation is subject to much greater local differences and anomalies than is the daily. Thus, in Siberia, the pressure is $\frac{8}{10}$ths of an inch less in July than in January. The great heat of Siberia in summer causes the air to expand and flow away in all directions. In winter, on the other hand, the great cold and small rainfall of that region cause high pressures to prevail. In Iceland and Orkney, again, the reverse of all this holds: the pressure is least in winter, and greatest in summer. The summer temperature of the North Atlantic, in which these islands are situated, is cool as compared with the heated continents that enclose it, hence there is an overflow from these regions into the basin of the North Atlantic, and therefore increased pressure; while in winter, the temperature there is comparatively high, causing an overflow of air towards adjoining countries, and a diminished pressure.

The distribution of atmospheric pressure is best exhibited by means of *isobarometric charts;* that is, charts on which lines are drawn through all places where the height of the barometer is the same. Such a chart may represent the mean pressure for the year, or the mean for a portion of the year, such as a particular month; or the readings of the barometer at a specified moment, such as the beginning or middle of a storm. Owing to the immense labour of collecting and arranging the hundreds of thousands of observations necessary for such a purpose, it is only recently that the attempt has been made. Mr Alexander Buchan, Secretary of the Scottish Meteorological Society, has the merit of first undertaking

* The quantity of rain which falls at any station during a given time is ascertained by means of the *rain-gauge*—an instrument constructed in various ways. One of the simplest forms consists of a cylindrical copper vessel furnished with a float: the rain falling into the vessel raises the float, the stem of which is so graduated that an increase in depth, to the extent of one-hundredth of an inch, can be ascertained. It is observed that rain-gauges collect different quantities at different heights above the ground, the amount being always greater at the lower level. This remarkable fact has never been quite accounted for.

the task; and a chart for the year, and one for each of the two months of July and January, published in his *Handy Book* in 1868, are the first-fruits of his labours. Ten more charts are to follow, so as to exhibit the progress of the annual variation, with its anomalies, throughout the year. It is easy to conceive that such a system of lines must throw great light on all inquiries regarding prevailing winds, the varying temperature, and the rainfall over the world.

The insight into the causes of atmospheric changes afforded by these charts, may be judged of from what Mr Buchan says in describing that for January: 'Over the North Atlantic occurs an extensive diminution of pressure, which deepens northwards till the greatest depression, 29·5, is reached in Iceland, or perhaps in a slightly lower depression nearly midway between that island and Spitzbergen. The widening of the isobarometric curves of 29·6 and 29·7 inches to the westward over Greenland, and to the eastward over the north of Norway and Russia, is an interesting feature of this area of low pressure. The low pressure of this region is due to the saturated state of its atmosphere and to the copious rainfall resulting from it. The flow of the Gulf-stream north-eastwards through the Atlantic to at least beyond Spitzbergen, and the larger amount of vapour poured into the atmosphere from its warmer waters, tends still further to lower the pressure. It is this low pressure over the North Atlantic, together with the high pressure to the eastward over Asia, which forms the key to the explanation of the winter climate of Europe.'

Distribution of Terrestrial Temperature.—The temperature of the earth differs not only in different regions of its surface, but at different elevations above or below the surface. In ascending a mountain or into the air in a balloon, the thermometer, as a rule, falls. The rate generally allowed is 1° of Fahr. for every 300 feet.* The increase of cold at high elevations arises from several causes. One cause is the rarefaction of the atmosphere, which takes place on ascending (see No. 15). Under ordinary circumstances, when a gas is allowed to expand, its temperature falls. This used to be explained by saying, that a gas when rarefied has a greater capacity for heat, and therefore requires a greater absolute quantity to keep it at a certain temperature. There is really, however, no change of specific heat, for it is possible, under certain conditions, to rarefy a gas without any loss of temperature. The real cause is that the gas in expanding performs *work;* it puts itself in motion to occupy the wider space, and no motion can be caused without expending some form of energy. The temperature of the gas depends upon some kind of oscillating motion among its molecules; part of this molecular motion is converted into a motion of translation, and the energy or heat of the gas is diminished by the amount thus expended. Another cause is found in the fact, that the sun's rays have little effect on the atmosphere, especially when dry, and only give out their full heat when they strike solid objects. It is thus the lower strata of the air that are in contact with the warm earth that derive most heat from the sun's rays. In addition to all this, the radiation, or loss of heat, goes on more rapidly, there being no solid objects around to return it, and the rarer air opposing less obstacle to its escape. At considerable elevations, too, there is proportionally less vapour in the air; and as it is the chief obstructor of radiation, objects in high regions are exposed naked, as it were, to the cold of the outer universe. At a certain height over every place, water will freeze, and if a mountain rise to this height, it will be covered with snow. The height over any place where water must be frozen at all seasons is called the *snow-line*, the altitude of which is greatest at the equator, and diminishes as the latitude increases. At a certain high polar latitude, it reaches the mean sea-level; that is to say, the ground at that level is eternally clad with snow.*

The law, however, of loss of temperature by elevation is subject to important exceptions. In winter, the earth is losing more heat by radiation than it derives from the sun's rays; therefore, in a dry, calm, clear night, the surface rapidly loses heat, and the stratum of air in contact with it is thus chilled below the general temperature of the atmosphere. The effect is most marked at short heights above the surface. The air in contact with the ground is frequently 15° or 20° below the air four feet above the ground; above four feet the differences are comparatively small. It is evident from all this, that in comparing thermometers, it is important that they be placed at the same height above the surface.

The effect of this chilling of the lower stratum of the atmosphere is modified by the configuration of the surface. From off heights and slopes, the chilled air flows down into the low-lying grounds, and there accumulates.

'This explains,' says Mr Buchan, 'why vapour becomes visible so frequently in low places, whilst adjoining eminences are clear; and the same fact instinct has made known to cattle and sheep, which generally prefer to rest during night on knolls and other eminences. Along most of the water-courses of Great Britain, during the memorable frost of Christmas 1860, laurels, araucarias, and other trees growing below a certain height were destroyed, but above that height they escaped.'

The variations of temperature below the surface belong rather to Geology and Physical Geography.

We have now to consider how heat is distributed over the earth's surface horizontally. The causes of the varying quantities of heat enjoyed by different places have already been described in a general way. The results of these causes, as modified by the varying relations of land and water, are made visible to the eye by means of charts having lines drawn through all places having the same temperature. These lines are

* According to the experiments made by Mr Glaisher in balloons, the diminution of temperature is 7·2° F. for the first thousand feet, but only 5·3° F. between the first and second thousand. From 14,000 to 15,000, it is reduced to 2·1°.

* The *snow-line* is found at various heights, according to latitude, proximity to the sea, and other causes, which affect the general climate of the region. In the Himalaya and Andes, it is found at an elevation of about 17,000 feet; in the Swiss Alps, at 8500 feet; and in the Scandinavian range, at 3500 feet. Generally, in those countries which are near the equator, the snow-line is found about 16,000 feet, or three miles above the sea-level: about the 45th parallel in either hemisphere, it occurs at an elevation of 9000 feet; under 60° of latitude, at 5000 feet or thereby; under 70° latitude, at 1000 feet; and under 80°, the snow-line comes down to the mean sea-level; for countries which are 10° distant from the poles are covered with snow all the year round.

called *isothermals* (Gr *isos*, equal, *therme*, heat), when they mark mean annual temperature; *isotherals* (Gr. *theros*, summer), when they mark either the mean of the summer months or that of the hottest month, July; and *isocheimals*, or *isochimenals* (Gr. *cheima* or *chima*, winter), in regard to winter. Fig. 1 is such a chart, exhibiting the distribution of the mean annual temperature; while fig. 2 exhibits the hottest and coldest months; the dotted lines marking the mean

Fig. 1.

Fig. 2.

temperature of January, and the solid lines that for July.

The part of the globe having the highest mean annual temperature forms an irregularly shaped belt, lying along the equator, and comprised between the north and the south isothermals of 80°. On either side of this warm belt the temperature diminishes towards the poles; and the lines shewing successively this diminution are, speaking in a very loose sense, arranged parallel to the equator, thus shewing the all-predominating influence of the sun as the source of terrestrial heat. The coldest portion of the earth's surface is a small oval-shaped patch near to but not surrounding the north pole, its mean temperature being −4°. Its narrowest diameter lies north and south, nearly touching the pole on the one side, and extending on the other as far south as 72°·30 N. lat. in 130° W. long. Part of it is seen in the diagram.

While the decrease of temperature in advancing towards the poles corresponds in a general way to what may be called the solar climate, there are deviations brought about by disturbing causes too important to be overlooked. The chief of these disturbing causes are (1) the currents of the sea; and (2) the prevailing winds.

Of ocean-currents affecting temperature, the most marked and important is the Gulf-stream in the North Atlantic, which, by conveying warm water to the arctic regions, pushes the isothermals many degrees to the northward. There is a similar, though much feebler, current passing from the North Pacific to the Arctic Sea through Behring's Strait, and there, accordingly, the isothermals are pushed a little to the northward. An opposite effect is produced by two cold currents from the Antarctic Ocean, flowing, the one along the coast of Peru, the other along the west coast of Africa.

Since winds bring with them the temperature of the regions they have crossed, the equatorial current is a warm wind, and the polar a cold wind; also winds arriving from the ocean are not subject to such variation of temperature during the year as winds from a continent. As an atmosphere loaded with vapour obstructs both solar and nocturnal radiation, it follows that moist winds are accompanied with a warm temperature in winter, and a cool temperature in summer; and dry winds with cold winters and hot summers. The direction of mountain-ranges is also an important element to be taken into account in estimating the influence of winds on temperature. These considerations explain the position of the isothermals in the north temperate zone, where the prevailing wind is the south-west or anti-trade. In January, the western parts of each continent enjoy a comparatively high temperature, from their proximity to the ocean, whose high temperature the winds waft thither; and they are further protected from extreme cold by their moist atmosphere and clouded skies. But in the interior of the continents it is otherwise; for the winds getting colder as they advance, and being deprived of their moisture as they cross the mountains in the west, the soil is exposed to the full effects of radiation during the long winter nights, and as a consequence, the temperature rapidly falls. In the centre of Siberia, the January temperature falls to −40°, which is 9° colder than the coldest part of the American continent; and this centre of greatest cold lies near the eastern part of the continent of Asia. On the other hand, in July, the interior of continents is much warmer than their western parts. Hence the interior and eastern parts of Asia and America are characterised by extreme climates, and the western parts by equable climates. Thus, at Yakutsk, in Siberia, the July temperature is 62°·2, and the January −43°·8, the difference being 106°·0; whilst at Dublin these are respectively 60°·8 and 38°·5, the difference being only 22°·3. This constitutes the most important distinction of climates, both as respects vegetable and animal life. On man especially the effect is very great—the severity of the strain of extreme climates on his system being shewn by the rapidly increasing death-rate as the difference between the July and January temperatures increases.

Winds and Storms.—Winds are classed as *Constant*, *Periodical*, and *Variable*. The Trade-winds and Return Trades constitute the first class; Sea and Land breezes, and Monsoons form the periodical class, and both have been considered under the general movements of the atmosphere.

Variable winds depend on purely local or temporary causes, such as the nature of the ground, covered with vegetation or bare; the physical configuration of the surface, level or mountainous; the vicinity of the sea or lakes; and the passage of storms. The hot, suffocating wind peculiar to Africa and Western Asia is known by the name of the Simoom; on the coast of Guinea it is called the Harmattan. A similar wind in Sicily and Italy is called the Sirocco, and in Spain the Solano. The *East Winds* which prevail in the British Islands in spring are part of the great polar current which at that season descends over Europe through Russia. Their origin explains their dryness and unhealthiness. It is a prevalent notion that the east winds in this country are damp. It is quite true that many easterly winds are peculiarly damp; all that prevail in the front part of storms are very damp and rainy, and soon shift round to some westerly point. But the genuine east wind, which is the dread of the nervous and of invalids, does not shift to the west, and is specially and intolerably dry. Deaths from brain-diseases and consumption reach the maximum in Great Britain during the prevalence of east winds. The *Etesian Winds* are northerly winds which prevail in summer over the Mediterranean Sea. They are caused by the great heat of North Africa at this season, and consist in a general flow of the air of the cooler Mediterranean to the south, to take the place of the heated air which rises from the sandy deserts. The *Mistral* is a steady, violent north-west wind, felt particularly at Marseille and the south-east of France, blowing down on the Gulf of Lyons.

Lord Bacon remarked that the wind most frequently veers with the sun's motion, or passes round the compass in the direction of N., N.E., E., S.E., S., S.W., W., and N.W., to N. This follows in consequence of the influence of the earth's rotation in changing the direction of the wind. Professor Dové of Berlin has the merit of having first propounded the *Law of the Rotation of the Winds*, and proved that the whole system of atmospheric currents—the constant, the periodical, and the variable winds—obey the influence of the earth's rotation.

The force of the wind is measured by *Anemometers*, of which some measure the velocity, by the revolution of vanes, and others the pressure. Of the latter kind is Lind's Wind-gauge, represented in the figure. When the instrument is used, water is poured into the tubes until the level in both stands at the middle of the scale. When no disturbing force acts upon either column of liquid, the level of both is accurately the same; but when the mouth of the tube AB is turned towards the wind, the column in AB is pressed downwards, and that in CD rises proportionably, and the difference of the heights of the two columns gives the column of water which the force of the wind sustains, and from this the pressure on a square foot is readily calculated.

Dr Lind's Anemometer.

The following are a few velocities of wind, translated into popular language: 7 miles an hour is a gentle air; 14 miles, a light breeze; 21 miles, a good steady breeze; 40 miles, a gale; 60 miles, a heavy storm; and 80 to 100 miles, a hurricane sweeping everything before it. We also add a few comparisons of velocity and pressure: 5 miles an hour is a pressure of 2 oz. on the square foot; 10 miles, ½ lb.; 20 miles, 2 lbs.; 30 miles, 4½ lbs.; 40 miles, 8 lbs.; 51 miles, 13 lbs.; 60 miles, 18 lbs.; 70 miles, 24 lbs.; 80 miles, 32 lbs.; and 100 miles, 50 lbs. During the storm in which the Tay Bridge was destroyed (Dec. 1879), the rate of velocity varied from 40 to 70 miles per hour, and the maximum velocity during the heaviest gusts was said to have reached 96 miles at Aberdeen. Wind is most frequently measured by estimation.

The estimate of the wind's force by the scale 0 to 12, means that 0 represents a calm, and 12 a hurricane. If such estimations be divided by 2, and the quotient squared, the result will be the pressure in pounds, approximately.

Storms are violent commotions of the atmosphere, occurring in all climates, particularly in the tropics, and differing from other atmospheric disturbances in the extent over which they spread themselves, their destructive power, and the sudden changes which take place in the direction of the wind. Numerous attempts have been made to reduce the phenomena of storms to general laws; but it is only quite recently that observations have been sufficiently numerous and accurate to furnish

the necessary grounds. The foregoing chart of Europe shews, from actual observations made at upwards of 100 localities scattered over that continent, the barometric pressure, and direction and force of the wind, at 8 A.M. of the 2d of November 1863, during part of the course of two storms which passed over Europe at that time. At the same hour of the previous day, the centre of the first storm (I.) was near Christiansund, and that of the second was approaching the west coast of Ireland. The isobarometric lines, or lines shewing where, at the above hour, the height of the barometer was the same, are given for every two-tenths in the difference of the pressure. Hence, where these lines approach near each other, or crowd together, the difference of pressure, or the atmospheric disturbance, was the greatest; and the least where they are most apart—a distinction of the utmost importance in determining where the storm may be expected to rage in greatest fury. The arrows shew the direction of the wind, being represented flying with it. The force of the wind is shewn (1) by plain arrows, ⟶, which represent light and moderate winds; (2) by arrows feathered on one side only, ⟶, which represent high winds; (3) by arrows feathered on both sides, ⟶, which represent strong gales, storms, or hurricanes.

Form and Extent of Storm Areas.—The circular isobarometric lines on the chart represent very accurately the general shape storms assume. The area of almost every storm is either circular or slightly elliptical. The outline is occasionally very irregular. The extent over which storms spread themselves is very variable, being seldom less than 600 miles in diameter, but often two or three times that amount, or even more.

Direction in which Storms advance.—It may be premised that by the direction of a storm is meant, not the direction of the wind, but the path followed by the centre of disturbance. The direction in which this progressive motion takes place differs in different parts of the world—being determined by the prevailing winds. Thus, about half the storms of Middle and Northern Europe travel from the south-west toward the north-east, and 19 out of every 20, at least, travel toward some point in the quadrant from the north-east to the south-east. Observation shews that the longer axis of the storm is almost always coincident with the direction in which the storm appears to be moving at the time. The storms of the Mediterranean follow a different course. Many of them proceed from the north to the south, influenced probably by the heated air rising from the Sahara. By far the greater number of the storms of North America take their rise in the vast plain which lies immediately to the east of the Rocky Mountains, and thence advance in an eastern direction over the United States; some of them, crossing the Atlantic, burst on the western shores of Europe. But the relation of the American to the European storms is not yet established. The storms of the West Indies generally take their rise from near the region of calms, and tracing out a parabolic course, proceed first towards the north-west, and then turn to the north-east about 30° N. lat., many of them traversing the east coasts of North America as far as Nova Scotia. South of the equator they follow an opposite course. The hurricanes of Hindustan usually pursue a parabolic path, first traversing the eastern coast towards Calcutta, and then turning to the north-west up the valley of the Ganges. The typhoons of the Chinese seas resemble, in the course they take, the hurricanes of the West Indies. Observations are wanting from other parts of the world to determine the course of storms.

Everywhere, the course tracked out by storms is determined by the general system of winds which prevail, modified by the unequal distribution of land and water on the surface of the globe. Facts seem at present to point to this general conclusion, viz., *Storms follow the course of the atmospheric current in which the condensation of the vapour into the rain which accompanies them takes place.*

The Rate at which Storms travel, varies from 15 or 17 miles an hour in Europe, to 30 or 40 miles in tropical countries.

Relations of Temperature, Rain, and Cloud to Storms.—The temperature increases a few degrees at places toward which and over which the front part of the storm is advancing, and falls at those places over which the front part of the storm has already passed. In other words, the temperature rises as the barometer falls, and falls as the barometer rises. When the barometer has been falling for some time, clouds begin to overspread the sky, and rain to fall at intervals; and as the central depression approaches, the rain becomes more general, heavy, and continuous. After the centre of the storm has passed, or when the barometer has begun to rise, the rain becomes less heavy, falling more in showers than continuously; the clouds break up, and fine weather ushered in with cold breezes ultimately prevails. It should be here remarked, that if the temperature begins to rise soon and markedly after the storm has passed, a second storm may be expected shortly. The rainfall is generally proportioned to the suddenness and extent of the barometric depression at the place where it falls.

Direction and Force of the Wind in Storms.—If the winds in Storm II. on the 2d November be attentively examined, they will be observed whirling round the area of low barometer in a circular manner, and in a direction contrary to the motion of the hands of a watch, with—and be this particularly noted—a constant tendency to turn inwards towards the centre of lowest barometer. The wind in storms neither blows round the centre of lowest pressure in circles, nor does it blow directly towards that centre, but takes a direction nearly intermediate. In other words, the whole atmospheric system flows in upon the centre in a spiral course. This rotatory peculiarity is common to all storms in the northern hemisphere that have yet been examined. In the southern hemisphere, a rotatory motion is also observed round the centre of storms, but it takes place in a contrary direction, or in the direction of the motion of the hands of a watch.

Professor Taylor has the merit of having first applied Dové's law of rotation to explain the direction of the rotation of storms round their centre. The cause may be seen by referring to Storm II. on the 2d November. On that morning, the pressure over England being much less than in surrounding countries, if the earth had been at rest, air-currents would have flowed

from all directions to England, to fill up the deficiency, in straight lines. The earth, however, is not at rest, but revolves from west to east; and as the velocity of rotation diminishes as the latitude increases, it is evident that the current which set out, say from Lyon to the north, would, on account of its greater initial velocity when it arrived at Paris, blow no longer directly to the north, but to a point a little to the east of north; in other words, it would no longer be a south, but a south-west wind. Again, since the current from the north of Scotland had a less velocity than those parts of the earth's surface on which it advanced, it lagged behind, and consequently, by the time it arrived at Silloth in the north of England, had changed from a north to a north-east wind. Similarly, the north-west current changed to a north, the south-west to a west, &c. Hence in a storm the whole system of winds rotates round the centre. It follows in the northern hemisphere that as storms advance, the general veering of the wind at places lying north of the path of their centre is from north-east by north to west; and at places south of their centre, from north-east by east and south to north-west; and conversely in the southern hemisphere.

Next, as to the force of the wind: The rule is simple, and without exception—viz., the wind blows from a high to a low barometer, and with a force proportioned to the difference of the barometric pressures. Hence, where the isobarometric lines crowd together, the violence of the storm is most felt, and where they are far asunder, the winds are moderate and light. We have stated that the progressive motion of storms varies from 15 to 40 miles per hour, which measures the time taken in passing from one place to another, but this gives no indication of the violence of the storm. This is determined by the rotatory velocity of the wind round the centre of the storm, which in Europe and America frequently amounts to 60 or 70 miles an hour continuously for some time. At Liverpool, on the 3d of December 1863, it blew in intermittent gusts with a speed of 93 miles an hour —a velocity frequently surpassed by storms within the tropics.

Of the different theories of storms hitherto proposed, we need only refer to the rotatory and the centripetal theories. The rotatory, or, as it is commonly called, the cyclonic theory, was first proposed by Piddington, and has since been elaborated by Redfield, Reid, Dové, and others. By this theory storms are considered as revolving round an axis either upright or inclined to the horizon, while at the same time the body of the storm has a progressive motion over the surface of the globe; the barometric depression, as caused by the centrifugal force, driving the air from the centre to the circumference of the storm. A fatal objection to this theory is, that observation conclusively shews that the wind does *not* rotate in a circle returning into itself, but constantly tends in a spiral towards the centre. Besides, the centrifugal force engendered by such a motion, even if it were a fact, would not be sufficient to depress the barometer at the centre to the hundredth part of the extent that actually takes place.

'The spiral rotation,' says Mr Buchan, 'instead of the purely circular rotation, of the winds in storms, completely alters the whole complexion of the question of the theory of storms. For since it follows from it that enormous quantities of air are constantly being poured all around into the area of the storm, and since, notwithstanding these accessions tending to increase the pressure, observation shews that the pressure is not thereby increased, but on the contrary sometimes diminished, *we are forced to the conclusion, that from a large area within and about the centre of the storm a vast ascending current must arise into the upper regions of the atmosphere; and arriving there must flow away over into neighbouring regions.* The physical cause of the ascending currents is to be found in the moist and warm, and therefore light, air which all observation shews to prevail in the front and in the central part of storms. And since most of the rain which accompanies storms falls in those parts of the storm, the barometer will be still further reduced by the removal of the elastic aqueous vapour which is condensed into rain-drops, and by the latent heat set free in the condensation of the vapour.'

An important point is to be able to tell in what direction the centre of a storm is from the place at which we are, and the rule is easy: 'Standing back to the wind, the centre lies to the left hand of the direction in which the wind is blowing. This holds in all places north of the equator, and it furnishes the rule which must be observed by ships in steering out of the course of the storm. From this relation of the winds to the pressure is also deduced the rule for predicting the direction of the wind at particular sea-ports during storms. Thus, suppose at 9 A.M. it be required to know the direction in which the wind will blow in London at 9 P.M., a storm being observed advancing from Ireland towards the east. Information being had through the telegraph of the course the storm is taking, and an inference being drawn from that observed course that at 9 P.M. its centre will be near Liverpool, then at that hour the gale may be expected at London from S.S.W.

Typhoons are violent storms that blow on the coasts of Tonquin, China, and Japan. They resemble the storms of Western Europe in their general characteristics, but the main features are more strongly marked. The central depression of the barometer is not unusually as much as 28·3 inches, and, on rarer occasions, even 27 inches.

Whirlwinds and Waterspouts.—Whirlwinds differ in many respects from storms or typhoons. They seldom continue longer than a minute at any place, and sometimes only a few seconds; their breadth varies from a few yards to nearly a quarter of a mile; during their short continuance, the changes of the wind are sudden and violent; and the barometer is not observed to fall. They are caused by two air-currents coming in contact and causing an eddy. The direction of the eddy of the whirlwinds, especially when the diameter is very small, differs from the rotation of winds in a storm, in that it may take place either way—right to left, or left to right—according to the direction of the stronger of the two winds which give rise to the whirlwind. In the sandy deserts of the tropics, these eddies draw up with them large clouds of dust, and the whole is borne forward by the wind that may happen to be blowing at the time.

Waterspouts are whirlwinds occurring on the sea or on lakes. When fully formed, they appear

as tall pillars of cloud stretching from the sea to the sky, whirling round their axes, and exhibiting the progressive movement of the whole mass precisely as in the case of the dust whirlwind. The sea at the base of the whirling vortex is thrown into the most violent commotion, resembling the surface of water in rapid ebullition. It is a popular fallacy that the water of the sea is sucked up in a solid mass by waterspouts, it being only the spray from the broken waves which is carried up.

What are sometimes called *waterspouts on land* are quite distinct from these phenomena. They are merely heavy falls of rain of a very local character, and may or may not be accompanied with whirling winds.

Weather-forecasts.—From the direct bearing weather-changes have on human interests, they have from the earliest times been closely watched, so that the causes by which they are brought about being discovered, their approach might be predicted with some degree of confidence. The craving in the popular mind for this knowledge is strongly attested by the prognostics of the weather current in every language, which, amid much that is shrewd and of considerable practical value, embrace more that is vague, and not a little that is positively absurd.

It may be laid down as a well established truth, that *no prediction of the weather can be made, in the British Islands at least, for more than three, or perhaps only two days beforehand.* Yet a belief in the prognostications of almanac-makers was once nearly universal, and is still prevalent.

The Moon and the Weather.—The belief is almost universal, that the weather is influenced by the phases of the moon. A *change* of the weather, either from foul to fair, or from fair to foul, may be specially looked for, it is thought, at the times of new and full moon, or even at the quarters, though these last are not considered so influential. This belief is found to be altogether without foundation.

The only predictions of the weather to be relied on are of the kind described in speaking of storms, where the telegraph comes into play. Almost all the weather-changes of Europe begin from the south-west, and pass over Great Britain to the north-east. Unsettled or bad weather is accompanied with a low barometer; elsewhere, the barometer is higher. Thus, then, suppose that, from weather-telegrams received, it is seen that everywhere in Europe barometers are high, we may be sure that no storm need be dreaded for two days at least. But if, on the following morning, barometers begin to fall a little in the west of Ireland, and an easterly wind begins to blow generally over Great Britain and Norway, and a south-east wind over France; then, since the winds blow towards the lowest barometer, or rather a little towards the right of it, the presumption is that a storm of greater or less severity is coming up, the centre of which is likely to pass over England. This ought, therefore, to be closely watched by the telegraph, and the indications announced from time to time.

It is our proximity to the Atlantic that makes it impossible to predict the weather beyond three days at the utmost. In Norway and the Baltic, and places towards the east of Europe, the weather may be predicted for a longer time, since each storm as it appears in the west may be followed in its course by the telegraph, and the places which it threatens be warned of the coming danger. In America also, where storms chiefly advance from west to east, gales and unsettled weather are predicted at the sea-board in the east some days before.

But the collecting of this information by the telegraph is a work which, owing to the expense, governments only can accomplish; and from its importance, it is an incumbent duty which they should discharge for the benefit of the seafaring population.

From all that precedes, it will be clear enough that the mere height of the barometer, at a particular place, taken by itself, affords no sure indication of what weather is coming; so that the terms Rain, Fair, Set Fair, marked on the common weather-glass, are delusive. The quantity of vapour in the air, the temperature, and the direction of the wind, are all to be taken into account. And with regard to the barometer itself, it is not so much the actual height that is of consequence, as whether it is rising or falling, and whether the rise or fall has been of long duration. A slow rise continued for some days gives promise of settled weather; a steady and long-continued fall indicates that a tract of unsettled and stormy weather may be expected. A sudden and great fall of the barometer is the sure forerunner of a violent storm.

CLIMATE.

The climate of a place depends on its distance from the equator, its height above the sea-level, its position in reference to oceans, seas, and continents, the form of its surface, and the character of its soil. The points to be stated in reference to climate are, the mean temperature, the extreme winter and summer temperatures, the range of temperature daily, and from day to day, the humidity, the total fall of rain, the frequency of the falls, the relation of the amount fallen to the ordinary amount of vapour in the air, the prevailing winds, and the degree of variability of the weather. In general, the southern hemisphere of the globe is colder than the northern.

The causes which determine most of these elements of climate have been already described; and the general results over the globe, as regards the most important element, temperature, are exhibited in the isothermal charts (page 42).

Under the geography of Great Britain and other countries, the peculiarities of their several climates will be noticed.

ELECTRICITY OF THE ATMOSPHERE.

Thunder and Lightning—Aurora Borealis.

The electric phenomena of the atmosphere possess great interest, but are as yet imperfectly understood (see ELECTRICITY). The discharges of the excitement are well known under the terms *thunder* and *lightning*, and they generally accompany storms and hurricanes, but rather as effects than causes.

The *aurora borealis*, one of the most beautiful of meteoric phenomena, is now believed to be connected with the *magnetism* of the earth.

LUMINOUS METEORS.

Rainbows—Halos—Parhelia—Coronæ, &c.

The various luminous appearances of the heavens, apart from the ordinary phenomena of sun, moon, and star light, are usually treated of under Meteorology.

The *rainbow* is owing to a complicated reflection and decomposition of the rays of the sun in passing through drops of rain. It appears when the sun is unclouded, and rain is falling in the opposite quarter of the heavens. The mode of its formation is more particularly explained under OPTICS. A morning rainbow is an unfavourable prognostic of the weather; a rainbow in the evening is favourable.

Halos are coloured rings occasionally seen surrounding the sun or the moon. There are often several circles, some concentric, others intersecting or touching one another. They arise from the minute snow crystals of the cirrus cloud, and are due partly to refraction and partly to reflection. It can be shewn by the well-known principles of prismatic refraction, that the common halo of 22° radius is owing to refraction by the faces of the crystals that are inclined to one another at an angle of 60°; while the wider circle of 46° radius is produced by faces at an angle of 90°. At certain points of the circles, other effects conspire to produce luminous knots called *parhelia* (mock-suns), or *paraselenæ* (mock-moons).

The true halos are to be distinguished from the *coronæ* that surround the sun or moon when a thin cloud passes over them. These depend on a different optical principle. The same appearances may be seen by looking at a candle through steam or through the dust of a room. The smaller the size of the particles, the greater is the diameter of the corona. A narrowing corona round the moon shews that the cloud particles are enlarging, and indicates coming rain. Coronas are less often seen round the sun, owing to the strength of his light.

One marked distinction between coronas and halos is, that in halos the red prismatic colour is next the centre; in coronas, the blue.

IGNEOUS METEORS.

Shooting-stars—Fire-balls—Aërolites.

Shooting-stars are observed during serene nights. A luminous point like a star bursts into view, shoots a certain way through space, and then disappears. Sometimes it leaves a luminous train behind it; in other cases it gives forth sparks. These meteors have been noticed to occur in great numbers at once; and the interest of such appearances has been very much increased by the fact of their being in some measure periodical. On several years they have been found to occur in the month of November. They also occur with some degree of frequency in August. Shooting-stars and *fire-balls* break out occasionally at every period of the year.

It is now agreed that these bodies are nothing else than small planets, and, therefore, the consideration of them properly belongs to astronomy. There is every reason to believe that the planets, satellites, and comets are not the only bodies which move round the sun, and lie within the solar system—they are merely the large conspicuous masses; while millions of others may exist, too small to be descried on ordinary occasions, and making themselves known by coming within the earth's atmosphere. The friction against the air, caused by their immense velocity, develops enormous heat, which melts the surface of the body, and this outer liquid portion is thrown off in a long flaming stream forming the train, which, after losing its velocity, is precipitated to the earth as a fine dust or volcanic ash, while the meteor, thus rapidly diminishing, either becomes wholly dissipated into tail, or falls to the earth, or makes its way out of the atmosphere, and continues its course. The periodic meteors are small bodies: they have been calculated to range from 30 grains to 7 or 8 pounds, and none of them have been known to fall to the earth. These smaller bodies, that are for the most part dissipated in the air, are the *shooting-stars*, properly so called. The irregular or sporadic meteors frequently come to the earth in large masses, and often burst in falling, owing to the outside being suddenly and intensely heated, while the interior remains cold. These *aërolites* (Gr. *aër*, air, and *lithos*, a stone) are found to consist of iron and stony matter in various proportions, the iron in some largely predominating. To account for the periodicity of the November meteors, it is imagined that a great number of them may move in a continuous ring or common orbit round the sun, so situated that the earth, in its annual course, brushes, as it were, with the outskirts of its atmosphere this ring of planetary fragments once a year. If the bodies were all round the ring, there ought to be a shower of them every November; but the great displays occur only once in about 33 years; and therefore it is inferred that the great mass of them are grouped at one part, and that the time of revolution of the ring being 33 years, that length of time must elapse between each concurrence of the earth and the dense part of the group.

One of the most familiar of luminous meteors is the *ignis-fatuus*, or 'Will-o'-the-wisp,' which appears at night on marshy grounds, places of sepulture, or wherever putrefaction and decomposition are going on. The appearance is that of a small flickering light, straggling in an irregular manner at the height of one or two feet from the ground, and sometimes standing for a few moments over a particular spot. When approached or pursued, the lights are agitated by the motion of the air, and seem to elude investigation. The cause of this species of meteor has never been satisfactorily explained.

Until recently, meteorological observations had been mostly casual and without any uniform plan; hence the vagueness and uncertainty that hang over so much of the subject. But since 1840, the earth has been covered with a net-work of meteorological observatories, maintained by the several European governments. Above all, the use of the telegraph in meteorology is proving a powerful means both of advancing the science and of turning it to practical account. It is not unreasonable to anticipate that, with the agents and apparatus now at work in this field, the next half-century may see light and order arising out of many things that now seem nothing but chaos.

PHYSICAL GEOGRAPHY.

GEOGRAPHY—from *gé*, the earth, and *grapho*, I write—in its simple and literal signification, is that science which describes the superficial appearance and conditions of our globe. It naturally divides itself into two great branches—1. *Physical Geography*, which treats of the earth as a superficies composed of land and water; considers the position, extent, altitude, and general character of the former; and the position, extent, depth, currents, and other motions of the latter: in short, all that relates to the distribution of land and water, variations of surface, temperature and climate, and distribution of plants and animals as dependent thereon, are the legitimate objects of this species of geography. 2. *Political Geography*, which treats merely of the division of the earth's surface by man into territories and states, describing their boundaries, the history of their occupation, their produce, commerce, population, laws, religion, and other topics which constitute the fundamental features of human polity. The latter of these branches will form the subject of several subsequent treatises; to an exposition of the former—dwelling more on principles than on mere descriptive details—we intend to devote the present number. Before doing so, however, it will be necessary to advert briefly to the cosmical relations and constitution of our planet, as determined by astronomy, geology, chemistry, and meteorology.

GENERAL CONSTITUTION OF THE GLOBE.

Astronomy informs us that the earth we inhabit is one of a number of *planets* which revolve round the sun as a common centre, constituting what is usually denominated the SOLAR SYSTEM. These planets are situated at different distances from the central orb, and differ also in their magnitudes, their densities, and in their periods of revolution. They are nearly spherical in form, are opaque, have no light of their own, but merely reflect that of the sun; and all move from west to east in nearly circular orbits. Several of them serve in turn as centres for other bodies of revolution, which are known by the name of *satellites*—as the moon, for example, which is the satellite or attendant of the earth. Besides the planets and their satellites, there is a third and numerous class of bodies belonging to the solar system—namely, *comets*, which revolve round the sun in regular periods, but in orbits so elliptical, that in parts of their course they approach nearer to the great orb than any of the planets, and in others recede so far into the regions of space, as to be entirely beyond the reach of our most powerful telescopes. The *stars* belong to other systems of revolution, and have, so far as has yet been determined, no perceptible effect upon the conditions of our globe, though undoubtedly bearing, like everything in nature, a universal harmonious relationship.

The earth, as an individual planet, is situated at the mean distance of 91,350,000 miles from the sun; has a mean diameter of 7912 miles; performs a revolution round the sun in 365 days 5 hours 48 minutes and 49 seconds, which constitutes the space of time called a year; rotates on its own axis once in 24 hours—that is, in one day; and in these movements is attended by the moon, which is distant 237,000 miles, is 2160 miles in diameter, and which completes her synodic revolution in 29 days 12 hours and 44 minutes, or in one lunar month. We have spoken here of the *mean* diameter of the earth, because, upon accurate measurement, it has been found to be not a perfect sphere, but an *oblate spheroid*, whose greater diameter is 7925, and whose lesser is only 7899 miles. This gives a difference of 26 miles between the two diameters, or a flattening at each pole of about thirteen miles—a result that may be artificially illustrated by twirling with rapidity a ball of any yielding material, such as putty, round a spit thrust through it as an axis, when a bulging at the outer circumference will take place, causing the ball to lose its original spherical form. This bulging takes place through what is called the law of centrifugal force; and from what we know of this law, it is concluded that the earth was in a soft or yielding state at the time when it assumed its present form. Besides the bulk, revolutions, and configuration of our globe, science has also determined its *density* with considerable accuracy. By weighing the most prevalent rocks, it has been found that the solid crust composed of them is about two and a half times heavier than water; but from experiments made on the attraction of mountains of known bulk, compared with the attraction and bulk of the globe, and by other means, it has been inferred that the density of the whole mass is five or six times that of water: in other words, the earth, as at present constituted, is five or six times heavier than a globe of water of similar dimensions, and more than twice the weight of one composed of such rocky substances as those with which we are acquainted. In addition to what may be called its own proper material, the earth is surrounded by a gaseous envelope or atmosphere. This *atmosphere* or air is peculiar to, and inseparable from, our globe—it rotates with the solid mass upon its axis, and does not, as may at first be supposed, occupy the space in which the rest of the heavenly bodies revolve. Like all aëriform and liquid masses whose particles press upon each other equally in every direction, the portions or strata next the earth are more pressed upon than those in higher regions; and continuing this conception, a height must be arrived at where the air becomes so attenuated as to be inappreciable. That limit used to be assumed at 45 to 50 miles; but there is evidence to shew that there is an atmosphere of some kind even at the height of 400 or 500 miles.

From its planetary relations, as a part of the solar system, the earth derives its figure and motions, its light and heat, and consequently the changes of season, and the alternation of day and night; the phases of the moon, and the rising and falling of the tides; the vicissitudes of wind and weather, and all the varied results and phenomena

that flow therefrom. Thus, while its figure is preserved by the laws of centripetal and centrifugal force, its motions are determined and influenced by the attraction and gravitation of the sun and other planets. From its situation with respect to the sun, it necessarily follows that only one-half of its surface can be exposed at a time to the light and heat diffused from that orb, thereby causing day in the one part, and night in the other. The *seasons*, again, are caused chiefly by the fact, that in performing its path round the sun, the earth preserves its axis in a slanting or oblique position, as has been more particularly explained in ASTRONOMY and in METEOROLOGY.

The solar system, however, vast as it seems, is but a unit in space, which is peopled with other systems and orbs circling beyond the bounds of human conception. What we term *fixed stars* are but suns and centres of revolution; and the solar system, as a whole, may revolve in space round some vast centre, just as its individual planets have their motions round the sun. From such a revolution may arise cycles of heat or cold, life or death, exuberance of certain living forms, and annihilation of others—cycles which meet with a faint analogy in the recurrences of our summers and winters. Even in the known relations of the earth to the sun, astronomers find causes of vicissitudes of temperature sufficient to account for those alternate periods of equatorial heat and glacial cold which geology shews our earth to have already passed through.

The materials of which the earth is composed present a history not less curious than that of its planetary relations. Superficially speaking, the globe consists of land and water—the water occupying the extreme depressions of the land, and this land composed of solid or rocky materials. Our direct knowledge of these materials extends only to a small depth—a mere rind of the globe; regarding the interior portions, we can only infer certain things. One of those inferences is that already noticed—namely, that the interior, as a whole, is more than twice as dense as the superficial matter. But whether this arises from the materials being different, or from their being more compressed, we have no means of knowing. It used to be held that the earth was a molten mass enclosed in a solid shell or cooled *crust*, through which the agitations of the liquid below produce the phenomena of volcanoes and earthquakes. From considerations, however, regarding the tides, and other astronomical data, it is inferred with certainty that this is not the case; and it is most likely that at least half the distance from the surface to the centre is solid and more rigid than the rocks we know. The solid earth to which we have access consists of rocks, differing not only in their appearance and arrangement, but in their mineral and chemical characters; some being compact and crystalline, as marble, others soft and dull, as chalk; some lying in layers or strata, others occurring in huge irregular masses; while, mineralogically and chemically speaking, we have such rocks as granite, quartz, slate, lime, coal, rock-salt, chalk, and clay. But the crust so composed, compact and solid as it may seem, is far from being permanent and stable; in other words, the dry land which now appears, with all its irregularities of hill and valley, plain and ravine, lake and river, is not the dry land which existed many thousands of years ago. Strictly speaking, indeed, the aspect of the globe is ever changing. Here the sea encroaches on the land, there the débris borne down by rivers silts up bays and estuaries; here earthquakes sink, and volcanoes elevate the surface; lakes are dried up, and rivers change their course; and, greater than all of these, vast regions gradually subside, and are covered by the ocean, while others as gradually emerge from the waters, and become dry land. All these changes, past and present, form the subject of geological consideration.

Geology, in its aim to decipher the physical history of our globe, has determined that all the known rocks may be ranked under two great sections—the *stratified* and the *unstratified*. The former appear in layers or beds, and have evidently been deposited in water, hence said to be *aqueous* or *sedimentary;* the latter appear in vast irregular masses, generally disrupting the stratified rocks,

and have all the appearance of having been formed like the lavas of the present day; hence they are called *igneous* or *volcanic*. Of the sedimentary rocks, sandstone, limestone, slate, and coal may be taken as illustrative examples; of the igneous, granite, basalt, greenstone, and lava are the most familiar. As at present, so in all time past, the surface of the earth has been subjected to atmospheric, aqueous, and other influences, the effects of which are to wear down the exposed material; and this, borne away by floods and rivers, is deposited in the ocean, where, consolidated by pressure, heat, and chemical agency, it forms new strata of rocks, which in time are brought to the surface by volcanic and other elevating forces. Thus, then, one set of agencies degrade, and another reconstruct and elevate; and in proportion as either of these preponderate, so will any portion of the earth be low and level, or high and precipitous. Such, then, is the origin of the stratified and unstratified rocks—the one but the reconsolidated matter of pre-existing rocks, which have been worn and battered down by rains, frosts, waves, and rivers; the other the cooled and hardened material sent forth from the interior of the earth by volcanic agency. But while rivers and floods bear down mud, sand, and the like, they also carry such vegetable and animal remains as lie in their course; and in this manner plants and animals are entombed in the newly formed layers or strata. As at present, so in former eras, such remains have been enclosed in the stratified rocks, where, subjected to certain chemical agencies, they have become petrified, and are thus preserved as records of the former Flora and Fauna which peopled the globe. Geologists have, accordingly, found that the earth has not always been occupied by the same kinds of plants and animals that now exist; but that different eras in its onward history have had very different Flora and Fauna, and that not one, perhaps, of the genera at one time in existence now survives.

By long-continued and widely extended observations in various parts of the globe, based on

numberless data of composition, structure, inclination, and fossil contents, geologists have been able to form a definite list of the various rock-formations from the earliest to the most recent, arranged in the order of time. They have divided the whole of the rocks composing the crust of the earth into sections called 'systems,' and have subdivided these again into 'groups,' in a certain well-defined order. So that when a rock is presented to their observation in any part of the globe, they can state, with more or less certainty, the system to which it belongs, and the period in the past history of the earth at which it was deposited. See GEOLOGY.

The constituents of all these rocks or strata, as well as those of plants and animals, are compounded of about sixty-three elementary substances; of which, at the ordinary pressure and temperature of the atmosphere, five are *gaseous*, and the rest mostly solid, by far the greater number being metals. See CHEMISTRY.

Of the constitution of the ocean, or watery portion of the earth's superficies, chemical research affords us precise data. When pure, water is composed of 1 part of hydrogen and 8 oxygen by weight, or of 2 hydrogen and 1 oxygen by volume. In nature, however, water is generally found to contain many impurities—such as clay, sand, animal and vegetable matter, &c.—which, if left at rest, by their own weight soon fall to the bottom. Such substances are said to be *mechanically suspended*, and when deposited at the bottom, form sediment. Besides impurities of this description, water may contain matter which will not fall down, and which is said to be held in *chemical solution*. The saline matter in sea-water amounts to about 3½ per cent. of its weight, or nearly half an ounce to the pound. It consists chiefly of common salt, sulphate of soda, carbonate of lime, chloride of magnesia, and silica, although more than twenty other substances have been detected in minute quantity. The saltness of the sea, however, is not quite uniform. In general, it is greater in the trade-wind regions than in extra-tropical; or wherever evaporation exceeds precipitation. A rainless sea, like the Red Sea, is considerably salter than the ocean generally; the Baltic, again, which receives a great many rivers, and is besides shallow, contains only half as much salt as the Atlantic. It is often found that while a comparatively fresh current is flowing one way on the surface, a salter undercurrent is setting in the opposite direction. A knowledge of the constitution of the ocean is necessary to the explanation of numerous facts in geology and biology.

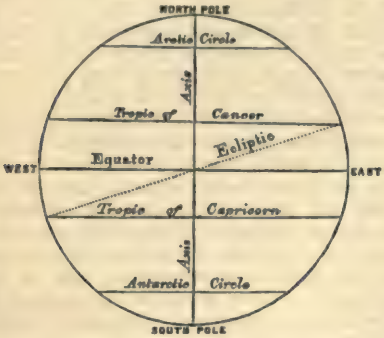
The *atmosphere*, the next great constituent of the globe, plays an equally important part in the organic and inorganic economy. As it presses with a weight of about fifteen pounds upon every square inch at the ordinary sea-level, and diminishes in density upwards in geometrical progression, it is evident that animals and plants fitted to live at small elevations will die if removed to great heights—a circumstance corroborated by the fact, that travellers experience difficulty in respiration on very high mountains. Notwithstanding its transparency, the air intercepts and reflects the sun's rays, and propagates them by an infinity of repercussions; and were it not for this property, objects would never be illuminated unless exposed to the direct light of the sun. The air—and more especially the watery vapour forming a part—is also the recipient and retainer of the heat radiated from the earth; and were it not so constituted, the heat derived from the sun's rays would be returned to space, and an excessive cold continually prevail. See METEOROLOGY. Chemically speaking, the atmosphere is a mixture of two gases, nitrogen and oxygen, in the proportion of 77 of the former to 23 of the latter, with about one part in 2000 of carbonic acid. In addition to these, which are its permanent constituents, there are always traces of ammonia and a certain amount of aqueous vapour, amounting from 1 to 1·8 per cent.; in certain localities, also minute quantities of other ingredients are to be occasionally detected. The atmosphere may therefore be regarded as the laboratory in which clouds, rain, snow, and other vapours are formed—the medium through which the light and heat of the sun are diffused and equalised—an element without which animal and vegetable life could not exist, for both incessantly inhale and exhale its elements; and an agent indispensable to those innumerable physical operations which constitute the progressive history of our planet.

Thus assisted by the determinations of astronomy, geology, chemistry, and meteorology, as regards the general constitution of the globe, physical geography proceeds to describe and explain its superficial appearance and conditions, and those, again, as influencing the life and distribution of the plants and animals by which it is peopled. Before entering, however, upon these interesting but complicated details, it will be necessary to explain the principal terms and technicalities usually employed by geographers.

GEOGRAPHICAL TERMS.

The direction from which the earth moves in its daily rotation is called the *West;* that towards which it moves, the *East;* the point which is on the right hand of one standing with his back to the east is called the *North;* that on the left hand, the *South.* The imaginary line on which the earth turns is called the *Axis;* its termination towards the north is known as the *North Pole;* that towards the south, the *South Pole.* The early cultivators of geography, dwelling on a part of the earth nearer the north than the south pole, supposed the former to be uppermost, though, in reality, such ideas as upper and under do not belong to astronomy; and it is for this reason that in globes and maps the northern part is always placed at the top, the east being towards the right, and the west towards the left hand, with the south at the bottom. Hence also the term *high latitudes*, applied to places lying far north. Exactly between the two poles, and consequently dividing the earth into two equal portions, is a line called the *Equator;* all north and south of which are respectively called Northern and Southern Hemispheres or Half-spheres. In the same way, an encircling line, at right angles to the equator, divides it into Eastern and Western Hemispheres. The circuit of the earth, both in its girth between east and west, and between north and south, is divided into 360 parts, called *degrees*, each degree being equal to about 69½ British miles. At the distance of 23½ of these degrees from the equator, in both directions, are two parallel lines called the

Tropics, because at these distances from the equator the sun *turns* in his annual path; they are known respectively as that of *Cancer* and that of *Capricorn*, from constellations situated in a corresponding part of the sky. At the same distance from each pole is a parallel line—that on the north being styled the *Arctic*, and that on the south, the *Antarctic Circle*. The space between the tropics



is called the *Torrid Zone*, because the sun, being always vertical in some part of that space, produces a greater degree of heat than is felt in regions where his rays strike more obliquely. The spaces between the tropics and the Arctic and Antarctic Circles are styled the *Temperate*, and the spaces within these latter circles, the *Frigid Zones*. Lastly, a line, which cuts the equator obliquely, touching upon opposite points of the tropics, is called the *Ecliptic;* it properly belongs to the sphere of the heavens. A series of lines drawn from pole to pole over the earth's surface, and cutting the equator at right angles, are called *Meridians*, from the Latin *meridies*, mid-day. Every place upon the earth is supposed to have one of these passing through it, although it is usual to describe only twenty-four upon the surface of the terrestrial globe. When any of these is opposite the sun, it is then mid-day, or twelve o'clock, with all the places situated on that meridian; and consequently midnight with those on the opposite meridian, on the other side of the earth.

The exact situation of a place upon the earth, or its latitude and longitude, is determined by means of these circles. They are all divided, as already stated, into 360 parts, which parts are called *degrees;* these degrees again into 60 equal parts, called *minutes;* the minute into 60 others, called *seconds;* and so on. They are usually indicated by certain signs—thus, $8^\circ\ 5'\ 7''$, is 8 degrees 5 minutes 7 seconds. The *latitude* of a place is its distance measured in that manner from the equator. If it lies north of that line, it is in north latitude; if south of it, in south latitude. There being only 360 degrees in the circumference of the earth, and the distance from the equator to either of the poles being only a fourth part of it, a place can never have more than 90 degrees of north or south latitude. The *longitude* of a place is the distance of its meridian from another, which is called the *first meridian*. The first meridian is quite arbitrary, and it is a matter of indifference through what point we draw it, provided it be settled and well known which one we adopt, so as to prevent mistakes. In Germany, the island of Ferro is generally adopted; in France, the observatory of Paris; and in England, that of Greenwich. Longitude is reckoned either east or west of the first meridian; and 180 is therefore the utmost degree of longitude. Some geographers, however, reckon longitude all the way round the globe. From the meridians all tending to a point at either pole, the degrees of longitude necessarily decrease as we approach these points from the equator.

Besides these terms and technicalities, which refer to the earth as a whole, there are others employed to designate its separate portions of land and water. Thus of the land, a *continent* is any vast region uninterrupted by seas; an *island*, any smaller portion surrounded by water; a *peninsula*, a portion nearly surrounded by water; an *isthmus*, the narrow neck which connects a peninsula with the mainland; a *cape*, *promontory*, or *headland*, a point of land jutting out into the sea. As to the water, a large uninterrupted extent of sea is called an *ocean;* smaller portions are known as *seas;* a bend of the sea into the land, a *bay;* a deeper indentation, a *gulf;* a narrow strip of sea, a *strait* or *channel;* and where the sea stretches inland to receive the waters of some large river, it is termed a *firth* or *estuary*. Referring to the surface of the land, without any reference to water, extensive flats are known as *plains*, *steppes*, *pampas*, &c.; smaller ones as *valleys*, *straths*, and *dales;* elevated land is spoken of as rising into *hills*, or, still higher, into *mountains;* and level elevated tracts are known by the name of *table-lands* or *plateaux*. Running water makes its appearance in *springs*, many of which conjoined form *streams*, and streams *rivers;* and where these become stagnant, and spread out into inland sheets, they take the name of *lakes*. The bounding-line of land and water is termed the *shore*, and the land bordering on the sea in any place is generally spoken of as the *coast* or *sea-board*.

DISTRIBUTION OF LAND AND WATER.

To exhibit the earth's surface at one view, it is usual to map it into two halves or hemispheres—the Eastern comprehending the one great continent of the *Old* World, or that known to the ancients; and the Western, or *New* World, discovered and explored since the close of the fifteenth century. To these, modern geographers add a third—namely, *Oceania*, or the Maritime World, partly situated in both hemispheres, and comprising Australia and the vast groups of islands which stud the Pacific Ocean. It will be seen at one glance that the sea and land are very unequally distributed—that they preserve no regularity of outline or form—and that either is placed indifferently as to position, on the earth's surface. Many fanciful conjectures have been offered to account for the configuration of the existing continents, but none of them seem to have any foundation in fact.

Though we are thus unable to account for the present relative arrangement of sea and land, there is one determining principle sufficiently clear—namely, that so long as the same quantity of water remains on the globe, a fixed amount of cubic space will be required to contain it. If the difference between the elevations and depressions of the solid crust be small—in other words, if the

hollows in which lakes and seas are spread out be shallow—their waters must extend over a greater superficial space; and if these hollows be deep, the waters will occupy less extensive areas. The operation of this principle should be borne in mind; for, if the inequalities of the land were generally less, the waters would occupy larger spaces, and this more extended area of shallow water would act in various ways. It would render the climate more genial and uniform; and, extending a greater surface to the evaporating power of the sun, rains and atmospheric moisture would be more prevalent. These, again, would influence the amount and kind of animal and vegetable life on dry land; while the shallow waters themselves would be more productive of life—it being a well-known fact that marine plants and animals flourish only at limited depths.

The proportion of dry land to water, as at present known, is about one to three—that is, nearly three-fourths of the whole surface of the globe may be assigned to water. Reckoning the entire area of the globe at 197 million square miles, the land is computed to occupy about 52 millions, leaving 145 millions for sea. The land is far from equally distributed over the globe; the greater part of it lies north of the equator. 'If,' says Professor Ansted, 'a person, stationed vertically over the town of Falmouth in England, could see half the globe, he would see more than 49 out of the 52 millions of square miles of land, or about an equal surface of land and water. If, however, he were perched equally high above New Zealand, he would see 96½ millions of square miles of water, and less than two millions of square miles of land.' To render this unsymmetrical protuberance of the land consistent with the right balancing of the globe, it has been assumed that the rocks in the water hemisphere may be heavier than those in the other, arising either from their containing more metal or being more compact.

CONTINENTS AND ISLANDS.

The continuous masses of land large enough to deserve the name of continents are only three in number—the Eastern Continent, or Old World; the Western Continent, or New World; and the Southern Continent, or Australia. By much the largest is the Eastern Continent; Europe, Asia, and Africa are, strictly speaking, not separate continents, but divisions or lobes of this vast tract. North and South America, in like manner, are the two divisions of the Western Continent. The areas of the three continents, with the adjacent islands, in round numbers of millions of miles, are as follows:

Old World, or Eastern Continent		31,230,000
Europe	3,724,000	
Asia	16,152,000	
Africa	11,354,000	
New World, or Western Continent		15,000,000
North America	8,200,000	
South America	6,800,000	
Southern Continent, or Australia		4,632,000

The outline and disposition of the three continents are as diverse as can well be conceived. The great mass of the Old World lies north of the equator, with its main axis ranging from north-east to south-west. The western continent runs, in its longest direction, nearly from north to south, and has considerably more of its area, in proportion, to the south of the equator than is the case in the other continent. Australia, again, is wholly in the southern hemisphere, has its greatest length from east to west, and is of a compact oblong shape, while the other two continents are excessively irregular and deeply indented. The Old and New Worlds agree in one remarkable circumstance; nearly all the projecting portions point southwards, and are mostiy of a triangular shape. This is seen, in the Old World, in Kamtchatka, Corea, Malacca, Hindustan, Arabia, Southern Africa, Italy, Greece, Spain, Scandinavia; and in the New, in Greenland, Alaska, California, Florida, and South America. Retaining the generally acknowledged divisions, let us glance at their respective positions and superficial characteristics as influencing the vitality of our planet.

Europe—lying almost wholly within the northern

temperate zone, diversified by a happy blending of mountain and plain, marked by no geographical feature on a scale so large as to give to its surface the character of monotony, and surrounded and intersected by seas which greatly influence its climate—affords, in proportion to its area, a habitat to a more varied and highly developed existence than any other quarter. Asia, situated partly within the torrid, temperate, and frozen zones, and presenting an area almost five times that of Europe, exhibits every species of geographical diversity. With such a variety of character, it is impossible to treat of it as a whole, and consequently geographers divide it into five well-marked regions—namely, *Central* Asia, consisting of a series of ascending plateaux, diversified by mountain-ridges of stupendous height, and intersected by narrow valleys; *Northern*, including the whole of the continent north of the Altaï Mountains—a flattish region traversed by large rivers, bleak and barren, suffering under an intense cold, thinly peopled, and almost physically incapable of improvement; *Eastern*—upon the whole a low-lying and somewhat arid region, though traversed by several of the largest rivers in the world, and occasionally diversified by spurs from the central table-heights; *Southern*, including the two peninsular projections of India within and without the Ganges—decidedly the finest region of the continent, diversified by minor hill-ranges and well-watered valleys, enjoying a high, though not an oppressive temperature, having only a rainy season for its winter, and, except during long drought, presenting in every district an unfailing verdure; and, lastly, *Western* Asia—from the Indus westward and north to the Caspian—which, with a few minor exceptions, may be said to consist of high sandy plains, studded with salt-lakes, very inadequately watered by rivers, and on the whole a hot and arid region. A continent marked by such a diversity of surface and climate, presents an appropriate field for the exhibition of almost every form of vitality known in the other continents; and thus has belief ever pointed to it as the cradle of organic existence. Africa, the next great division of the Old World, is almost entirely insular, the isthmus connecting it with Asia being only seventy-two miles across, of no great elevation above the sea-level, and even in part occupied by lakes and salt-marshes. It is only a few years ago that little was known regarding the physical construction of Africa beyond a limited strip around the coast, and a few tracks across the Great Desert of the north. Thanks to the adventurous explorations of recent travellers, we now have a tolerable notion of its general features. One of these features is an almost continuous range of mountains girdling the continent round, leaving a belt of lowlands of from 50 to 300 miles broad between them and the coast. In the triangular part of the continent, south of Cape Guardafui and the Gulf of Guinea, the interior consists of an elevated plateau variegated by mountain tracks, river-valleys, and depressions containing great lakes; the whole abounding in multiform vegetable and animal life. North of this plateau the interior consists of the comparatively low-lying and fertile track known as Nigritia and the Great Desert or Sahara. The isolation of Africa, its intertropical position, and its general configuration, must stamp it with *vital* peculiarities; and yet its connection with Asia on the one hand, and its proximity to Europe on the other, offer numerous facilities to the interchange of vegetable and animal species. Thus the southern and northern sea-board of the Mediterranean present many similar forms; and the Flora and Fauna of Egypt and Nubia are identical in many instances with those of the adjoining tracts of Arabia.

Turning now to the New World, we find also the two Americas so slenderly attached by the narrow rocky Isthmus of Panama, which at one part is little more than eighteen miles across, that they may safely be regarded as separate and distinct continents. This separation is rendered still more decided by the irregular character of the isthmus and the adjoining high table-land of Mexico, which form an almost impassable barrier to the migration either of animal or of vegetable races. South America lies chiefly within the tropics, a third part or less stretching southward into the temperate zone; its superficies is broadly marked by mountain and plain, exhibiting along the entire western coast a flat arid region, from 50 to 100 miles in breadth; then rising boldly up into the Andes, which stretch along its whole length, and present a rugged irregular region of variable breadth; and ultimately falling away to the north and east in the *llanos* of the Orinoco, the *plains* of the Amazon, and the *pampas* of La Plata. Nor are its physical features more broadly marked than the plants and animals by which it is peopled, these exhibiting typical peculiarities only next in degree above those of the somewhat anomalous continent of Australia. The problem of the north-west passage being now solved, Greenland and a number of islands lying west of it might be conveniently erected into a new geographical division. Following, however, the usual course of including these regions, the area of the known continent of North America may be stated at 8,200,000 square miles—the great mass of which lies within the northern temperate zone. The general physical characteristics of the continent are remarkable for the magnitude of the scale upon which they are presented—the plains, lakes, and rivers being superior to those of all other countries. Though lying chiefly within the temperate zone, its southern and northern regions are respectively placed under tropical and arctic influences; and thus it presents in some measure the threefold variety of Fauna and Flora which characterises the greater continent of Asia. This greater diversity of climate renders it less peculiar in its living forms than the sister continent, at the same time that its proximity to Asia—being separated by Behring's Strait, which is only thirty-six miles broad—renders the immigration of Old-World species by no means improbable.

In estimating the comparative adaptability of a land as the habitation for man, an important element is the extent of its coast-line compared with its area. The more irregular the shape of the land, and the more it is broken into by gulfs and bays, the more are the inland parts brought into proximity to the great highway of intercourse and civilisation. Europe is so indented with seas and gulfs, that it has a coast-line of 20,000 miles, while the same area might be contained in a regular figure of 6000 miles' circuit. Had it had an outline of this kind, it would hardly have been, as it is,

the habitat of the most advanced races. The following table exhibits the number of square miles of area to one mile of coast in the several large divisions of land, thus affording a measure of the comparative accessibility of the interior:

Europe	157 sq. miles of area to 1 mile of coast.		
Asia	528	"	"
Africa	738	"	"
North America	266	"	"
South America	440	"	"
Australia	340	"	"

The *insular portions* of the globe are not less worthy of notice than the continents themselves. We find them sometimes solitary, oftener collected into groups or *archipelagoes:* in some cases they are little more than low sand-banks, ledges of rocks, or coral reefs; and in others—rising to a considerable elevation above the surface of the water, and spreading to a considerable extent—they present in miniature all the features of the continents to which they belong. They are often the summits of submarine mountain-chains, and, as such, are intimately connected with each other and with the neighbouring mainland. Many of them are evidently the production of volcanic forces—the dawn of new continents emerging from the waters, as others are the gradually submerging relics of former terrestrial regions. The most important island-groups are the British, Japan, Philippine, and East Indian in the eastern hemisphere; and the West Indian and Polynesian in the western. The largest individual islands (regarding Australia as a continent) are—Borneo, with an area of about 280,000 square miles; Madagascar, 234,000; New Guinea, whose outline is yet imperfectly known; Sumatra, 177,000; Niphon, 109,000; Great Britain, 90,000; Nova Zembla, 25,000; Newfoundland, 40,000; Cuba, 43,400; and Iceland, 40,000 square miles.

Islands, we have said, are either connected with existing continents, are portions of former continents now submerged, or are new and independent elevations. Thus, if an island is of the same geological formation with the adjoining mainland, we must regard it either as a portion separated by depression, or as a belated portion only rising into dry land. In either case, we are bound to consider it in all its relations—vital as well as physical—as belonging to the adjacent continent. Again, islands of totally different formation from that of the nearest continent may in most cases be regarded either as relics of former lands, or as new lands rising into day; and we are not to be startled at the fact of their exhibiting—like Australia—races of plants and animals altogether peculiar.

Such is a brief glance at the partition of the dry land (so far as it is known) into continents and islands—a partition which exercises an all-important influence over organic existence, and which, after all, is dependent on very minute geological operations. A general elevation of the solid crust in the eastern hemisphere, for example, would connect Britain with the continent of Europe, the Lofoden Islands with the Scandinavian peninsula, enlarge the connection between Asia and Africa, elevate the Sunderbunds of the Ganges into a vast plain, the Laccadive and Maldive reefs into extensive islands, and the bed of the Yellow Sea into an alluvial plain. Equally important results depend upon the relative positions of the continents and islands. Had South America, unaltered in a single square yard, lain parallel with, instead of crossing, the equator, or had Africa been intersected by seas, as Europe is, it requires no stretch of imagination to conceive the radical difference which their Flora and Fauna would have presented. As regards man, and the highest aim of creation—the civilisation of man—the present arrangement is of the first importance. The theatre of his operations all arctic, and he would never have risen above the condition of the Laplander or Esquimaux; all antarctic, and behold his condition in that of the miserable Fuegian; all tropical, and see him in a state of languid, enervated, semi-civilisation; while balanced as conditions are, see his progress mainly in one broad zone, where Chinese, Indian, Persian, Chaldean, Syrian, Egyptian, Greek, Roman, Frank, and Anglo-Saxon have successively or simultaneously figured in the march of improvement.

MOUNTAINS AND TABLE-LANDS.

As elevation above the waters of the ocean is the origin of the dry land, so its most prominent features are those peculiar upheavals known by the name of *hills* and *mountains.* The theory of their upheaval belongs to Geology; but according to their character, so is that of the regions to which they belong, generally speaking, determined. They subserve numerous and important purposes in nature. Rising into regions of perpetual ice, they serve, in hot climates, to temper the air with the breezes generated around their heights; they are the reservoirs of rivers, supplying the shrinking streams, in the dry seasons of the lower countries, with copious torrents from their melting snows; they are in most instances the storehouses of the richest minerals; they increase and diversify the surface of the earth; and, by presenting impassable barriers between opposite regions, they give variety and richness to animal and vegetable life: we say impassable barriers, for the broadest seas are not half so effective in obstructing the dispersion of vegetable and animal life as lofty snow-clad mountains.

Isolated mountains of great height are of rare occurrence, and when they do appear, are usually active or recent volcanoes. Hills and mountains, whether rising to the height of 1000 or 20,000 feet, generally appear in chains or ranges, consisting either of one central chain, with branches running off at right angles, or of several chains or ridges running parallel to each other; and in both cases often accompanied by subordinate chains of minor elevation. Several chains constitute what is called a *group;* and several groups, a *system.* The relative ages of mountain-chains appertain more especially to the province of the geologist; but with their epochs is connected their physiognomy or contour, a subject eminently interesting to the geographer. So persistent is the contour of mountains, whether associated with the older or more recent formations, that the practised eye of the geologist can generally determine at a glance the era of their upheaval. The bold, but bald and massive heights of a granitic mountain differ widely in aspect from the abrupt and splintery crags and pinnacles of the older stratified formations; while the rounded, undulating, and terraced outline of the secondary trap-hills distinguishes them at once from the conical crateriform heights of the

tertiary era. Nor is it in appearance alone that these distinctions are interesting; the cold barren subsoil of a granitic district, altogether independent of elevation, differs as widely in its vegetable exhibitions from those of a fertile and congenial trap, as a cultured garden does from a moorland wild.

Respecting the classification of mountains, various plans have been adopted by continental writers; but most of them are objectionable, as involving geological theories: we shall adhere to that simpler arrangement which takes into account merely their geographical position and connection. Those of Europe have been classified into a number of systems, some of which are continental, others insular. Laying aside minutiæ, the following seem to be distinct and natural: 1. The *Hesperian*, embracing the mountain-ridges of the Spanish peninsula—all of which maintain a wonderful parallelism in position, as well as unity of character, and whose extreme culminating point is Maladetta, in the Pyrenees, 11,168 feet. 2. The *Gallic* system, including all the hilly eminences in France which lie to the north of the Garonne, west of the Rhone, and south of the Rhine. None of these are of great age, or of great elevation, the highest being a peak of the Plomb de Cantal, in Auvergne, 6113 feet. 3. The *Alpine* system, embracing all those ridges and branches which radiate from the great Alpine range of Switzerland, such as the Maritime, Cottian, Pennine, Rhetian, Noric, and other Alps; the Apennines in Italy, and the Balkan or Hæmus group in Turkey. The highest or culminating point is Mont Blanc, in Switzerland, 15,732 feet. 4. The *Hercynio-Carpathian* system, including all the mountains and eminences comprehended between the Rhine, Dnieper, and Danube, the plains of Northern Germany and Western Poland. The highest point in this system is Lomnitz, in the Central Carpathians, upwards of 8000 feet. 5. The *Scandinavian*, a system of the highest antiquity, embracing the well-defined chains of Norway, Sweden, and Lapland, the extreme height of which does not much exceed 8000 feet. 6. The *Ural* system or chain, which forms the boundary-line between Europe and Asia, and rises in its highest part to between 5000 and 6000 feet. Lastly, the *Britannic* system, consisting of a number of detached chains, as the Grampians, Cheviots, and Welsh mountains, the highest point of which is Ben Nevis, in Inverness-shire, 4406 feet. All of these systems, as axes of elevation, have long ago become fixed and permanent; none of them has for the last two thousand years shewn symptoms of volcanic activity: Hecla, Vesuvius, and Etna, the only active volcanoes in Europe, seem to point to future upheavals.

The mountains of Asia may be all traced from that vast central plateau already adverted to, which forms, as it were, the nucleus of the continent. Omitting ranges of minor altitude, we may enumerate—the *Altaï*, an Alpine girdle (greatest height 12,790 feet), running along the 50th parallel of latitude from the 84° of longitude to Lake Baikal, and continued eastward in the Daurian system and Stannovoi mountains, which are supposed to stretch to Behring's Strait; the *Khin-gan* range, bounding the Desert of Gobi on the east, but of unknown altitude; the *Thian-shan* and *Kuen-lun*, two ranges beginning in the west of Chinese Tartary, and running eastward—the former about the parallel of 42°, the latter about 36°—into China; attaining in some summits a height of upwards of 20,000 feet, and remarkable as containing active volcanoes at a distance of 1500 miles from the sea; the great *Himalaya* mass, extending about 1500 miles in length, and from 100 to 160 across, rising from the Indian side by stages of 4000, 8000, and 11,000 feet to a mean elevation of 18,000 or 20,000 feet, attains in several peaks the height of about 25,000, in Dhawalagiri 26,826, in Kinchinjunga 28,156, and in Mount Everest 29,000—probably the greatest elevation on the globe; the *Hindu Kush*, with their southern ramifications, which may be regarded as prolongations of the Himalaya; and, lastly, the *Tauro-Caucasian* system, diversifying the west of Asia with numerous ridges and peaks, the highest of which are Elburz, 18,493 feet, and Demavend, 21,000. In connection with these systems and ridges are active volcanoes, as in Kamtchatka, Japan, the Thian-shan ranges, &c.

The mountain-systems of Africa are as yet only partially known. The hills of Cape Colony rise from Table Mount, 3582 feet, to the summits of the Nieuveldt and Snieuveldt mountains, in the north of the colony, which are estimated at 7000–10,000 feet; the spaces between the ranges being broad elevated terraces or *karoos*, connected by shrubby *kloofs* or valleys. Beginning with Cape Colony, one vast table-land, the greatest on the globe, occupies the south of the African continent, stretching on the east as far north as Nubia. The mountain-ranges seen running parallel with the east coast form the border of this table-land; the highest of them yet seen is Kilima-Njaro, between 3° and 4° south latitude, estimated at 20,000 feet. The Abyssinian mountains form a terminating cluster to the range, reaching in the Abba Jared, at the extremity of the table-land, the height of 15,000 feet. The Cameroons, on the west, are above 13,000 feet; some of the summits around the great equatorial lakes in the interior rise to 10,000, but none of them, apparently, into the region of snow. On the north, between the Sahara and the Mediterranean, the *Atlas* system is well defined, and here an elevation of 11,400 feet has been ascertained.

The mountains which traverse South America may be ranked under two systems—the *Cordillera of the Andes*, and the *Mountains of Brazil.* The former, in several parallel chains, extend along the western edge of the continent from the Strait of Magellan to the Caribbean Sea, in many places spreading out over a breadth of several hundred miles, embracing lofty table-lands, containing mountain lakes, and everywhere intersected by steep narrow ravines and passes. A remarkable feature of the Andes is that the parallel ranges frequently come together, forming lofty table-lands called *knots.* At Popayan, the main chain divides into three ridges, one of which, shooting off to the north-west, passes into the Isthmus of Panama; a second separates the valleys of the Cauca and Magdalena; and a third, passing off to the north-east, separates the valley of the Magdalena from the plains of the Meta. The most elevated portion of the system is the Bolivian Andes, from south lat. 21° to 14°, numerous summits of which rise to 13,000–22,000 feet. The highest peak of the

system is in Chili, where Aconcagua is 22,300 feet—perhaps the highest volcano in the world; Chimborazo, in the equatorial Andes, is 21,424. Altogether, the Andes present a most magnificent spectacle to the voyager on the Pacific; the snow which permanently covers their lofty summits, even under the burning sun of the equator, contrasting beautifully with the deep blue of the sky beyond; while occasionally another contrast is exhibited in vast volumes of smoke and fire, emitted from some of the numerous volcanoes which stud the entire range. The Brazilian mountains occupy a great breadth of country, but seldom exceed an elevation of 6000 feet.

The chief mountain-system of Central and North America may be considered as a continuation of the Andes of the south, the whole forming, as it were, the backbone of the New World, and extending from Cape Horn to the Arctic Ocean, a distance of nearly 10,000 miles. The Cordilleras of Central America, or Mexican Andes, as they are sometimes called, extend from the Isthmus of Panama to the north of Mexico. They spread themselves, for the most part, from sea to sea. At Panama, where the range is crossed by a railway, the elevation is under 300 feet; but it increases towards the north. The greater part of Mexico consists of magnificent table-lands from 5000 to 9000 feet high, girt and intersected by mountain-ranges, with peaks—several of them volcanic—rising above 17,000 feet. Within the United States and British America, the system is known by the general name of the Rocky Mountains. It consists of several parallel ranges running in the general direction of the Pacific coast, and between that coast and the head-waters of the streams that flow into the Mississippi, and extending over a tract 1000 miles broad from east to west. The eastern range or axis, which forms the main water-shed between the basin of the Mississippi and the Pacific, rises in Fremont's Peak to 13,570, and farther north, in Mount Brown, in British America, to 16,000. The western or Maritime range attains, in the Sierra Nevada of California, a height of 14,000; and in Mount St Elias, on the coast, in lat. 61°, a height of 17,800. The Alleghanies or Appalachians, on the east side of the continent, extend in parallel ranges, with valleys between, from Alabama to Main; the highest summit of the system is Mount Washington, in New Hampshire, 6634 feet.

In Oceania we have several minor groups and ranges; but the principal elevations are in detached volcanic heights, the index-fingers, as it were, to future mountain-systems. In Malaysia, the highest known point is Mount Ophir, in Sumatra, 13,850 feet. The east coast of Australia is bordered by a range of no great elevation; but a backbone runs through the islands of New Zealand, near the west coast, attaining a height in some peaks of 10,000 to 12,000 feet. The highest points in Polynesia are the active volcanoes of Mauna Kea and Mauna Loa, in Hawaii, each about 14,000 feet.

Such are the more prominent mountain-systems as known to geography. Those who regard them as mere ridges, rising on one side, and descending as abruptly on the other, and at most intersected by a few narrow passes, gorges, and ravines, form a very erroneous conception of the physical contour of the globe; for, so far from this being the case, most of these systems are but the escarpments or ramparts of elevated expanses known as *plateaux* or *table-lands*, which form in some instances the nucleus of continents, and the source from which the rivers of such continents flow. Thus, on examining the map of Asia, it will be seen that all the rivers flow—north, east, south, and west—from the central region, which in reality forms a succession of remarkable plateaux. These plateaux may be termed the Persian, which ranges from 3000 to 6000 feet above the sea; the Mongolian, at an elevation of from 8000 to 12,000 feet; and that of Tibet, which reaches 17,000. There are some masses of this kind in Europe, but of comparatively small extent—as the central part of Spain, which is about 2200 feet in height; and the Swiss table-land, between 3000 and 4000 feet. The elevation of the great South-African plateau seems to be highest towards the east side. In South America, the city of Potosi, in Bolivia, is situated in the elevated valley of Desaguadero, at 13,600 feet above the sea-level; and the plateau on which Quito stands has an elevation of 9000 feet. One of the most noted table-lands is that of Mexico, not less remarkable for its elevation than for its extent.

EARTHQUAKES AND VOLCANOES.

These are rather agents than effects—rather the cause of geographical diversity than geographical features themselves; and in this respect belong more properly to the province of geology: still, as much of the superficial irregularity is the direct result of their operations, and as it is often impossible to separate cause from effect, it will be necessary here to give them some further consideration.

Volcanoes affect the external features of the earth chiefly by the matter they eject from its interior. By the discharge of lava, loose stones, scoriæ, fine dust or volcanic ash, and other materials from these vents, multitudes of isolated conical mountains have been formed; valleys have been filled up by the lava-streams, and woods, villages, and cattle have been buried. The immense volumes of steam generally discharged during an eruption condense into rain, and mixing with the ashes, form torrents of mud, little less destructive than the rivers of lava. A mud avalanche from Vesuvius overwhelmed the ancient Roman cities of Pompeii and Herculaneum in 79 A.D. As an example of the enormous masses of material thus poured out from the interior of the earth, we may cite Etna in Sicily. It reaches a height of nearly 11,000 feet, with a circumference of about ninety miles, and is composed entirely of lava and ashes thrown out from many different points around the central cone. There are several hundreds of volcanoes now in activity, and there is evidence that they once existed in many places where they have long been extinct. In Auvergne, in the centre of France, there are lofty mountains of lava, and numerous cones of loose cinders rise into conspicuous hills, each with its crater, while congealed streams of lava can be traced down the plateau into the valleys. Yet all is cold and still, and has been so for unknown ages. Sheets of lava are still conspicuous in the British Islands; but they have

been so long exposed to the wasting of the elements, that no actual crater can now be traced. Volcanoes for the most part occur in lines, and not far from the sea; partly along the margins of the great continents, partly in chains of oceanic islands. The most remarkable example of the marginal arrangement is seen in the long chain of volcanic vents that studs the western border of America from Tierra del Fuego to Mexico. Of insular volcanoes the most numerous and energetic occur in the Indian Archipelago—Sumatra, Java, and the adjacent islands. Along the island of Java there runs a band of not less than forty-five volcanoes, most of which have been seen in eruption.

But the forces, whatever they are, that produce volcanoes and earthquakes do not always act in this violent paroxysmal way. They are constantly producing movements and changes on a vastly greater scale than anything resulting from earthquakes and volcanoes, but so gently and insensibly, that it is only by the results which they bring about in a long course of years that we can detect their operation. Without shaking or rending the earth, they succeed, in the end, in elevating vast tracts of land above the sea, or in depressing them beneath it. The *raised beaches* which form so marked a feature in the scenery of many parts of the coasts of the British Islands, are evident proof of such a gradual upheaval. The Scandinavian peninsula, except a part of its southern end, is even now slowly rising; in some districts, at the rate of two or three feet in a century. But the most marked elevation of a continuous kind is that which is taking place along the western coasts of South America. Evidences of the opposite movement—a gradual sinking of the land—are also abundant. The extreme south of Sweden is undergoing sensible depression; and submerged forests on several parts of the British coasts point to a like operation. The most striking proof, however, of subsidence of the earth's crust is furnished by the coral islands of the Indian and Pacific Oceans. The characteristic form of the coral island is a ring of white rock enclosing a lagoon of still water, the walls of the ring rising for the most part perpendicularly from immeasurable depths. Now the polypes that form these rocks can only live at a moderate depth, and it has been satisfactorily established that these ring-islands had their beginning in *fringing reefs* of coral such as are now seen off the shores of existing land. Let us suppose that one of these fringing reefs encircles some oceanic island, and that the sea-floor in that region is being slowly depressed. As the downward movement continues, the corals keep building up the reef to about the level of the waves. In this way the space of water between the island and the coral ring is greatly increased, while, of course, the area of the island itself is correspondingly lessened. The downward movement continues—the island grows less and less, until its last mountain-top sinks beneath the sea. Over the submerged island there now stretches a smooth sheet of green water known as a *lagoon*. Encircling it is the circular reef of coral, or *atoll*, along the outer margin of which the restless waves of the ocean are ever surging. Soil gradually forms on the reef, seeds borne to it by the waves or carried by birds take root, and the ring of coral reef becomes a habitable spot for man. Such is the history of the growth of the coral islands. They have been built round the summits of a sinking continent, over whose mountains and valleys the great ocean now rolls.

What may be the nature of the force which produces these upheavals and subsidences, those quakings and eruptions, how it originated and how it is kept up, are questions to which, as yet, no very definite answer can be given. It is clear, indeed, that heat plays a large part in producing these changes. The temperature of the earth is found always to increase as we descend into the crust; and if the rate of increase which has been observed were to continue without any modification, we should reach the melting-point of even the most refractory substances at the depth of a few miles. But, for reasons already given, the old notion that there is still a central liquid part in an incandescent state, with a thin crust over it liable to be shaken and broken through by the commotions of the fluid interior, cannot now be held.

That the interior of the earth, however, whatever be its composition, is intensely hot, is indicated by all the evidence we can gather on the subject. Some portions must be liquid, as is shewn by the discharge of fluid lava at a white heat from volcanic vents. There seems, indeed, to be good reason to believe that though the main mass of the interior may now be solid, there nevertheless exist within it large lakes or reservoirs of melted rock, and that volcanoes serve as the orifices of communication between these areas and the surface. When the water which is everywhere traversing the upper layers of the crust reaches these heated spaces, it is converted into steam, which exerts an enormous expansive force. The abundance with which steam is given off during volcanic eruptions has long been familiar, and serves to indicate that steam may be the agent more immediately employed in forcing melted lava to the surface. During the changes which are in progress underneath, a mass of water will sometimes be suddenly precipitated into an area of intensely heated rock, and its instant expansion will produce a sensible concussion or earthquake above ground.

The constant transference of materials from the interior to the surface, whether by the action of volcanoes or by that of springs, must necessarily produce cavities within the crust. When, for example, we contemplate such a mountain as Etna, and reflect that all its vast piles of lava, scoriæ, and ashes have been abstracted from the interior of the earth, we see how real and important is this transference of material, and how easy it is to conceive of the formation of large hollow spaces beneath the surface. Again, the amount of solid material removed by springs, though it does not stand up before us as an enduring monument like Etna, is probably in reality greater in any one year over the whole globe, than all the lava and ashes which have been erupted by volcanic action during the same period. By some springs, such as those of a thermal kind, the quantity of these materials carried off in a single year would, if collected and rendered visible, make huge mounds or even small hills. Alike, therefore, by the action of volcanoes and the subterranean circulation of water, cavities must be

produced within the interior of the earth. As these become enlarged, their roofs, from failure of support, will sometimes give way with a sudden collapse. Such is not impossibly the origin of many earthquake shocks. When we know that even on the surface the explosion of a powder-magazine sometimes gives rise to a tremor of the ground, which is felt at a distance of several miles, we may conceive how the collapse of one of these underground cavities, and the consequent rushing together of thousands of tons of rock, may send a pulsation for many miles through the elastic crust of the earth.

The slow rising of some parts of the surface is accounted for by supposing that among the internal movements of the earth a great mass of rock may gradually have its temperature raised, and thus be expanded so as to push up the crust lying above it. In like manner, if the rock cools down, a slow depression of the overlying region will be the result. But without supposing an actual increase of temperature in any part, both upheaval and subsidence may be accounted for by the gradual cooling of the earth as a whole. As the nucleus shrinks in dimensions, the outer coat becomes too large for it, as it were, and has to accommodate itself by going into frumples, bending inwards in one part, and outwards in another. The inequalities on the surface of the globe have thus a similar origin to those on a shrivelled apple; or, to vary the figure, continents and sea-beds, mountains and valleys, are the wrinkles that mark the aging of mother earth.

PLAINS, VALLEYS, AND OTHER DEPRESSIONS.

The plains, or level portions of the earth's surface, form a feature in its physical aspect equally important with that presented by its mountain-systems. The name is given to extensive tracts whose surface in the main is level, or but slightly broken by elevations and depressions. They are found at all elevations above the sea, and of every degree of fertility; from the exuberant tropical delta just emerging from the water, to the irreclaimable sterility of the desert of ever-shifting sand.

The noblest of these expanses are the river-plains of the New World, drained by such waters as the Mississippi, the Amazon, and La Plata. Much of the Mississippi plain is rolling or undulating in its surface, well watered by minor rivers, exhibiting broad grassy *prairies* and extensive pine-forests. In South America we have first the low belt of country skirting the shores of the Pacific, from 50 to 100 miles in width, and about 4000 in length, fertile at its extremities, but in the middle sandy and arid; next, the basin of the Orinoco, consisting of extensive plains called *llanos*, either destitute of wood, or merely dotted with trees, but covered during part of the year with tall herbage; then the basin of the Amazon, a vast plain, embracing a surface of nearly 2,000,000 square miles, possessing a rich soil and humid climate, and almost entirely covered with dense forests and impenetrable jungle-marshes by the river-sides; and, lastly, the great Valley of the Plata, occupied chiefly by open plains called *pampas*, in some parts saline and barren, but in general clothed with weeds, thistles, and tall grasses. Next, in order of importance, is that section of Europe extending from the German Sea, through North Germany and Russia, towards the Ural Mountains, presenting indifferently tracts of heath, sand, and open pasture, and regarded by geographers as one vast plain. So flat is the general profile of this region, that it has been remarked, 'it is possible to draw a line from London to Moscow, which would not perceptibly vary from a dead level!' Passing the Ural ridge, a plain of still greater dimensions stretches onward through Siberia, towards the shores of the Pacific. This region is of no great elevation, and, though diversified by occasional heights, consists chiefly of gravelly steppes, covered with coarse herbage, lakes, and morasses. In Africa, the northern and central portion, so far as explored, appears to be a vast expanse of Sahara, or sandy desert, broken at scanty intervals by oases of life and verdure.

Certain minor tracts in these wide expanses receive distinctive designations. These are the verdant *prairies* of North America, already noticed, the *pampas* and *llanos* of South America, the *steppes* of Asia and Northern Europe, the *tundras* or bog-marshes of Siberia, the grassy *karoos* of Southern Africa, the tangled *jungles* of India, the alluvial *straths* or *dales* of our island, and the low muddy, but gradually increasing *deltas* of such rivers as the Ganges, Nile, Niger, and Mississippi. To lesser flats and depressions—as valleys, glens, ravines, &c.—which give character to the landscape of particular districts, our space will not permit us to refer.

THE OCEAN.

The ocean, though in fact a single mass of fluid resting in the hollows of the solid crust, surrounding the dry land on all sides, and indenting it with numerous bays and gulfs, is generally divided by geographers into the following great basins: The *Pacific* Ocean, 11,000 miles in length from east to west, and 8000 in breadth, covering an area of 50,000,000 square miles; the *Atlantic*, 8600 miles in length from north to south, and from 1800 to 5400 in breadth, covering about 25,000,000 square miles; the *Indian* Ocean, lying between 40° south, and 25° north latitude, is about 4500 miles in length, and as many in breadth, covering a surface of 17,000,000 square miles; the *Antarctic* Ocean, lying round the south pole, and joining the Indian Ocean in the latitude of 40° south, and the Pacific in 50°, embraces an area—inclusive of whatever land it may contain—of 30,000,000 square miles; and the *Arctic* Ocean, which surrounds the north pole, and lies to the north of Asia and America, having a circuit of about 8400 miles. Besides these great basins, there are other *seas* of considerable extent, as the Mediterranean, covering an area of 1,000,000 square miles; the German Ocean, 153,700; the Baltic, 134,900; the Black Sea, with its subordinate gulfs and branches, 181,000; but these and other minor sections will be more appropriately described when we come to treat of the respective countries (Volume II.) with which they are politically as well as physically associated.

Respecting the depth of the ocean, our knowledge has recently become much more definite and certain, owing to improvements in deep-sea sounding. The floor of the North Atlantic, in particular, is nearly as well known as the most of

terra firma. Proceeding west from Ireland, the bottom descends in a succession of steps or terraces, sometimes of immense extent. The descent from one plateau to another is sometimes by steep cliffs 9000 feet deep. The greatest depth is some distance south of the great bank of Newfoundland, where there is a basin-shaped depression 1000 miles in length, with soundings of about 30,000 feet, or above five miles and a half. The bottom of the Pacific is less known: soundings of 40,000 feet have been obtained.

The temperature of the sea, where it is not affected by currents from a warmer or colder region, necessarily corresponds to that of the air above it; but this is true only of the water at and near the surface. In the Mediterranean, for example, the surface temperature ranges from 80° in summer to 54° or 55° in winter. But this excess of summer heating does not extend beyond a depth of 100 fathoms: below this, the temperature of 54° or 55° is maintained constantly at all depths; and this temperature is that of the crust of the earth in that region. In the Atlantic, in the same latitude, the temperature of the upper stratum of 100 fathoms does not essentially differ from that in the Mediterranean; but at greater depths, the temperature sinks to 49°, 40°, 38°, 36°, and in some places to the freezing-point of fresh water, and even below it (29·6°). Recent observations tend to shew that an almost glacial coldness prevails over the whole deep-sea bed in both hemispheres, extending even to the tropics. The cause of this phenomenon will be explained when we come to speak of the currents of the ocean.

The sea consists of salt water, as already adverted to, and from its continual motion, under the influence of currents and waves, preserves, generally speaking, uniform saltness. Under special circumstances, however, we find the saltness increased, as by the excess of evaporation over the fresh-water influx in the Mediterranean and Red Seas, and about the northern and southern limits of the tropical belt; and decreased, by the contrary cause, in the Sea of Azof, Black Sea, Baltic Sea, and in the polar regions. The origin of the saltness of the sea is sufficiently accounted for when we consider that the chloride of sodium and other soluble salts which form constituent ingredients of the globe, are being constantly washed out of the soil and rocks by rain and springs, and carried down by the rivers; and as the evaporation which feeds the rivers carries none of the dissolved matter back to the land, the tendency is to accumulate in the sea. The principal ingredients found in sea-water are chloride of sodium, or common salt, together with salts of magnesia and lime. The mean quantity of salts of all kinds in the ocean is 34·4 parts in 1000. In some parts of the Mediterranean the salinity is as high as 39·26, and of the Red Sea 43; while in the Baltic and Black Seas, it varies from 18 to 12. Of the mean of 34·4 parts, about 24 are due to chloride of sodium, 4 to chloride of magnesium, nearly as much to sulphate of soda, one part to carbonate of lime, and ·25 or one part in 4000 to silica. Upwards of thirty different elementary substances have been already detected in sea-water, and spectrum analysis may yet reveal more; but, except those named above, they exist mostly in exceedingly minute proportions, so that it is only in the analysis of sea-weeds, marine animals, and the stony matters deposited in marine boilers, that their presence can be detected. But when we consider the vastness of the ocean, the absolute quantity of even the minutest ingredient must be enormous. The silver dissolved in the sea would far transcend 'the wealth of Ind.'

The specific gravity of the water of the ocean varies, of course, with the salinity; the average is 1·0272. Another effect of the salinity is that, while fresh water freezes at 32° F., the water of the ocean requires to be reduced to 28°; and the ice then formed is porous and full of a briny fluid —the solid ice in fact is fresh.

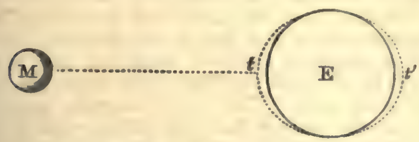
The *colour* and *phosphorescence* of the ocean are the next sensible properties requiring attention. When examined in small quantities, sea-water is colourless; but when viewed in the mass in the wide ocean, it appears to be of an azure or blue tint. The cause of this generally blue colour has not been as yet clearly explained; it would seem that the blue rays of light are more readily reflected from masses of a transparent fluid. While there can be no doubt that the ocean is generally of a blue colour, it is equally certain that there are many portions of sea in which a different hue appears. The causes of these exceptions from the rule seem to be of various kinds. Frequently the ordinary colour of the sea is affected by the admixture of foreign substances, these being sometimes of a living and organic nature, and sometimes not. Another class of cases in which the ocean appears to be tinged with a peculiar colour, is referable to the reflection of rays of light from the bed or bottom; and hence, in shallow and clear seas, the colour of the ground is a main cause of any particular tint which the water may there assume.

The phosphorescence of the ocean, described in such glowing terms by almost every voyager in tropical seas, is now satisfactorily ascertained to arise sometimes from the presence of infusorial animalcules, and at others from the decomposition of vegetable and animal matter. Similar phenomena, arising from similar causes, exist on land—the glowworm, fire-fly, certain fungi, putrid fish, &c.—and their appearance in the one element need not excite greater surprise than their exhibition in the other.

TIDES—CURRENTS—WAVES.

The waters of the ocean are subject to various motions and fluctuations, such as tides, currents, whirlpools, waves. That regular ebb and flow known by the name of *tides*, and which confers on the ocean one of its most interesting features, is caused by the attraction of the sun and moon. By the universal law of gravitation, all masses of matter have a tendency to be attracted or drawn towards each other. The moon, therefore, as a mass of matter, in passing round the earth, has a tendency to draw the earth after it, or out of its natural relative position; and it really does so to a small extent. As it passes round, it draws up the waters in a protuberance, or, in common language, draws a huge wave after it. But it also draws the whole solid globe—though to a less extent than the water immediately under it—and so causes the opposite side of the globe to be drawn away from the ocean, leaving the waters

there to form a similar protuberance or high wave. In the one case, the water is drawn directly up or towards the moon (M); in the other, the water is



in some shape left behind by the land being pulled away from it. In both a similar effect is produced: two tides (t, t') are caused at opposite extremities of the earth. Where the higher part of either of these great billows strikes our coasts, we have the phenomenon of high-water; and when the lower touches us, it is low-water. Each of the waves is brought over any given place in the circumference of the earth in twenty-four hours, so as to cause high-water twice a day. The sun exerts a far greater attractive influence on the earth than the moon does; but from the great distance of that luminary, the *difference* of that attractive force on different parts of the globe is much less, and therefore the effect in raising tides is comparatively small. But when this minor influence of the sun coincides with that of the moon, or acts in the same line of attraction (Mt), we perceive a marked increase in the tides; on such occasions we have what are called *spring* or *large* tides. When the solar and lunar attractions act in opposition, we have *neap* or *small* tides. The spring-tides happen twice a month, when the moon is at full and change; and the neap when the moon is in the middle of its orbit between those two points. A tide requires six hours to rise—which it does by small impulses or ripplings of the water on the shore—and six hours to ebb or fall; but every successive high-water is from twenty to twenty-seven minutes later than the preceding, or, on an average, about fifty minutes for two tides, in consequence of the earth requiring that time above the twenty-four hours to bring any given point again beneath the moon. The tides are thus retarded by the same reason that makes the moon rise fifty minutes later every day. It is evident that the tides will be greatest at that point of the earth's surface which is nearest to the moon, or where the latter is vertical. She is so between the tropics; and accordingly the tides are there greatest, and they diminish as we approach either pole. It is further to be remarked that the moon does not anywhere draw up the tides immediately. In consequence of the law of inertia and of fluid friction, the tidal wave lags behind the moon. Moreover, in consequence of all the great seas and oceans forming, as we have seen, only one sheet of water variously distributed, the ebb and flow in each depend not on its own proper tide, but are the result of the combination of that tide with currents mingling with it from tides of other seas—a result depending upon inequalities of sea-bottom, the configuration of its coasts, their inclination under water, the size and direction of the channel which connects it with other seas, and occasionally upon winds and currents which are not tidal. So much do these circumstances affect the astronomical or *primary* tidal wave, that while it rises in the expanse of the Pacific to one or two feet only, the *derived* wave often rises in confined or obstructed seas to elevations of thirty, fifty, or even a hundred feet! Inland expanses of water, like the Baltic, Mediterranean, and Caspian Seas, and the lakes of North America, have no perceptible tides.

Besides being affected by the regular motion of the tides, the ocean is pervaded by a system of *currents*, mostly constant, which has been compared to the circulation of the blood. These currents play a most important part in modifying the climates of different regions. As respects the causes of oceanic currents, much remains to be cleared up; but some of the leading causes seem well established. The two prime movers are differences of temperature and prevalent winds. Sea-water does not freeze until it is cooled down to about 28°; and, unlike fresh water, it continues to grow heavier down to that point. The effect of the intense cold of the polar regions is thus to cause a constant sinking down of the surface, and to establish a current of ice-cold water along the bottom towards the equator; while, to supply the place of what sinks down, an in-draught or northward flow takes place on the surface, which brings the warm water of the temperate and tropical regions towards the poles. This is the general theory of the *vertical* circulation of the ocean—a circulation which might almost be assumed from the well-known laws of the flow of liquids, and which recent observations have established as a fact. The general prevalence of cold currents along the bed of the ocean from the poles to the equator is now beyond dispute. Motion once thus begun, however, is differently modified in each locality by the shape of the coasts, by prevalent winds, and other circumstances. But one cause which modifies all currents that tend either north or south, is the daily rotation of the earth. At the equator, any spot on the surface is moving eastward at the rate of 1000 miles an hour; at 60° north latitude, the velocity is only one half. Thus, the water of a current starting from the equator northward, is constantly coming to places where the bottom under it has less and less eastward velocity. But, by the law of inertia, the water tends to retain the same velocity eastward with which it started, and thus it moves to the east of north—shooting ahead, as it were, of the bottom over which it is flowing, as a rider does whose horse slackens his pace. The contrary happens to a stream flowing from north to south. In this case, the eastward motion or motal inertia of the water is too slow for the parts of the bottom to which it successively comes; the bottom slips in a manner from under it, and it falls to west of south. This, in combination with the action of opposing coasts, accounts for the circular sweep which many of the currents make, returning partly into themselves.

Different in origin from this vertical circulation, though partly mixed up with it, is the *horizontal* circulation caused by prevalent winds. The best example of this is the Equatorial Current, which sets from the west coast of Africa to the east coast of Brazil, and which is owing to the action of the trade-winds. Currents caused by winds are always shallow, and their rate of motion seldom exceeds half a mile an hour: they are called 'drift-currents,' in opposition to the deeper-seated 'stream-currents.' In order to feed this westerly equatorial current, there spring up two *in-draught* currents—the one from the north along the west coast of Portugal and Morocco,

the other from the Cape of Good Hope along the west coast of Africa as far as the Gulf of Guinea. When the equatorial current reaches the coast of Brazil, it divides into two branches. One proceeds southwards, turning gradually eastwards across the Atlantic until it falls in with the northern in-draught from the Cape of Good Hope. The other branch is deflected northwards into the Caribbean Sea and the Gulf of Mexico. The water thus driven into this pent-up sea now rushes with accumulated momentum through the strait or gulf between Florida and the Bahamas, and forms the famous Gulf Stream.

The Gulf Stream, after issuing from the Florida Strait, proceeds at first northward, parallel to the American coast; but between the parallels of 35° and 37°, it turns gradually eastward, passing over the southern extremity of the Bank of Newfoundland, and all the while expanding in breadth and becoming shallower. The temperature of the stream, when it starts, is from 83° in summer to 77° in winter, and even after travelling 3000 miles to the north, as high as the Banks, there is a difference in a winter day between its water and that of the surrounding ocean of 20° to 30°. Along its whole course a cold arctic current underlies it; and this arctic current intervenes between the western border of the stream and the coasts of Florida, Georgia, and the Carolinas, the line of demarcation between the two being so abrupt that it is known as the 'cold wall.' At the bow of a ship entering the Gulf Stream the temperature has been found to be 70°, while it was only 40° at the stern. The velocity of the stream, at its outset, is from 50 to 60 miles a day; but this velocity becomes greatly reduced as it proceeds.

It has usually been held that the Gulf Stream extends across the Atlantic to the shores of Northern Europe, and is the cause of the mild and moist climate enjoyed by the western parts of that continent. The opinion, however, is beginning to prevail that, as a distinct current, the Gulf Stream ceases in the middle of the North Atlantic, its waters being by this time thinned out to a mere film, and its initial velocity and distinctive heat having been dissipated. That warm waters from tropical seas are brought to the coasts of Britain, and even into the polar seas beyond, is proved by drift-wood, seeds, and fruits from the West Indies being frequently cast ashore on the Hebrides, the north of Norway, and Spitzbergen. But this is accounted for by the general flow of the surface-water towards the poles, forming part of the vertical oceanic circulation; a flow which receives an eastward deflection as it proceeds northwards in the way above explained. This general set of the surface-water is further promoted by the prevalence of south-westerly winds or return-trades, which maintain a pretty constant north-east *drift* over the whole surface of the north-eastern portion of the Atlantic. In this way, although the Gulf Stream may have lost its original impetus, a large portion of the superheated water which it brings into the centre of the Atlantic, must be carried to the shores of Europe and into the Arctic Sea. Before, however, the Gulf Stream loses its force as a distinct current, it sends off a branch southwards by the Azores which re-enters the equatorial current before described.

While the climate of the west of Europe is thus ameliorated by having its shores washed by waters from warm seas, and by the moist and warm south-westerly winds that predominate, the corresponding coast of America is, at least, as much depressed by a current from the Greenland seas which flows southward along the shores of Labrador, carrying with it immense fields of polar ice, and accompanied by dry and piercing winds from the north and north-west. This arctic current intervenes between the coast of America and the Gulf Stream, as already mentioned, and flows under it into the Gulf of Mexico.

The currents of the Pacific Ocean are little known; but the Indian Ocean, exposed to a tropical sun and hemmed in on the north, sends out several large currents of warm water. One is the Mozambique current; another escapes through the Strait of Malacca, and flows past China and Japan into the Pacific, making for the north-west coast of America. This current resembles in many respects the Gulf Stream.

Two currents of equal force, but of different directions, meeting in a narrow passage or gut, will cause a *whirlpool*, a phenomenon which has ignorantly been said to be produced by subterranean rivers, gulfs, chasms, &c., but essentially is only an eddy. Charybdis, in the Strait of Sicily, and the Maëlstrom, on the coast of Norway, are eddies of this kind, alternately absorbing and casting up again whatever approaches them.

Being an elastic and mobile fluid, water is readily acted upon by winds; and thus *waves* are produced, varying in height and velocity according to the force and continuity of the wind, extent of uninterrupted surface, depth of the ocean, contending currents, and the like. The common cause of waves is the friction of the wind upon the surface of the water. Little ridges or elevations first appear, which, by continuance of the force, gradually increase until they become the rolling mountains seen where the winds sweep over a great extent of water. The velocity of waves is in proportion to the square root of their length. The large waves just spoken of proceed at the rate of from thirty to forty miles an hour. It is a vulgar belief that the water itself advances with the speed of the wave; but in fact the *form* only advances, while the *substance*, except a little spray above, remains rising and falling almost in the same place with the regularity of a pendulum. A wave of water, in this respect, is imitated by the wave running along a stretched rope when one end is shaken. But when a wave reaches a shallow bank or beach, the water becomes really progressive; for then, as it cannot sink directly downward, it falls over and forward, seeking the level. Sailors and others speak of waves running 'mountains high;' but, according to Scoresby, 43 feet is about the utmost difference of level between crest and trough in ocean-waves.

LAKES AND RIVERS.

Lakes are inland bodies of water not connected with the ocean or any of its branches: they are generally fresh, but are occasionally brackish, or even decidedly salt. They are classified according as they are fresh or saline, and according to the manner in which they receive and discharge their waters—namely, those that both receive and discharge running water; those that receive waters,

but have no visible outlet, as the Caspian Sea; those which receive no running water (being fed by springs), but have an outlet; and such as neither receive nor discharge running water. Lakes are distributed over the globe according to the inequalities of surface; and all tend to annihilation, partly by silting up their basins, and partly by deepening their outlets, thereby effecting an entire drainage of their waters. The most gigantic are those of North America—such as Superior, Huron, Michigan, Erie, and Ontario, which respectively occupy 32,000, 20,000, 16,000, 10,000, and 7200 square miles. Next in order are the lakes of Africa, three of which—Victoria Nyanza, Albert Nyanza, and Tanganyika—are estimated at 29,900, 25,400, and 10,400 respectively. The largest lakes in Asia are Aral and Baikal; the surface of the former is estimated at 23,000, and the latter at 15,000 square miles. Europe can boast of a vast number, which, though generally small, give beauty and diversity to her landscapes. Those of Ladoga and Onega, in Russia, are the largest; the former having a surface of 6330, and the latter of 3280 square miles. A comparative estimate of the extent of these vast sheets may be formed when we mention that the area of Lake Geneva does not exceed 340 square miles.

Lakes subserve important purposes in the economy of nature. They serve as reservoirs for the waters which rivers would too speedily carry away from the land; they are the tanks, as it were, in which the impurities of streams subside; they refresh and enliven the landscape; and as they all tend to silt up their own sites, these sites become in time tracts of fertile alluvium, and such has been the origin of some of our finest plains.

Rivers, streams, springs—whether flowing with a volume several miles in breadth, or trickling in a tiny rill which a child's hand might obstruct—constitute a class of the most valuable agencies in the physical history of our globe. They are the irrigators of its surface, adding alike to the beauty of the landscape and the fertility of the soil; they carry off impurities and every sort of waste débris, to be deposited in the ocean as the strata of future continents; and when of sufficient volume, they form the most available of all channels of communication with the interior of continents. Rivers originate in the rain and snow which descend from the sky (see METEOROLOGY). Falling on the surface, the water percolates the soil, finds its way through the rents, fissures, and pores of the rocky strata, and ultimately escapes at some lower level in the form of *springs*. Some of these springs are perennial, others temporary or intermittent: some are limpid, and almost absolutely pure; others are impregnated with metallic, earthy, and saline ingredients, according to the nature of the strata through which they have percolated: some are cold, others tepid; while many issue, with bubbling and steam, near the ordinary boiling-point of water. Springs, naturally tending to lower levels, unite and form *streams;* and these, again, falling still lower, conjoin in valleys, and form *rivers*—creating in their course rapids, cataracts, and waterfalls, ravines and dells, lakes, swamps, and marshes, alluvial plains, and low terminating deltas. The valley in which a river flows is usually termed its *basin;* and its *drainage* is that portion of country drained by its streams or tributaries; the terms are often used synonymously. To compare merely the lengths of rivers is far from conveying a correct idea either of their physical or economical importance; the extent of their basins is an equally important item. The following is a comparative view of the length and drainage of some of the principal rivers on the globe, headed by the Thames as a standard of comparison.

PRINCIPAL RIVERS.	Length in Miles.	Drainage in Square Miles.
EUROPE—		
Thames	250	600
Vistula	530	75,000
Loire	530	45,250
Rhine	800	86,000
Elbe	600	58,800
Don	900	224,000
Dnieper	1000	226,000
Danube	1750	250,000
Volga	2320	500,000
ASIA—		
Euphrates	1800	260,000
Indus	1800	250,000
Ganges	1500	300,000
Yang-tze-kiang	3600	700,000
Amoor	2700	780,000
Obi	2000	1,350,000
AFRICA—		
Nile	5000(?)	(?)
AMERICA—		
St Lawrence	2000	297,000
Mississippi—Missouri	4400	1,244,000
La Plata	2000	1,250,000
Amazon	4000	2,000,000

CLIMATOLOGY.

The climatology of the globe relates to the degree of heat and cold to which its respective countries are subject, the dryness and moisture of the air, and its salubrity or insalubrity as influenced by these and other causes. As yet the minutiæ of climate are but imperfectly determined; the following general causes, however, have been sufficiently ascertained: 1. The action of the sun upon the soil and atmosphere; 2. The internal heat of the globe; 3. The height of the place above the sea; 4. The general exposure of the region; 5. The direction of its mountains relatively to the cardinal points; 6. The neighbourhood of the sea, and its relative position; 7. The geological character of the soil; 8. The degree of cultivation which it has received; and 9. The prevalent winds. These causes, acting together or separately, determine the character of a climate as moist and warm, moist and cold, dry and warm, dry and cold, &c.; and this climatic character is the main influence which determines the nature and amount of vegetable and animal development. The several subjects belonging to this section are treated in detail in the number on METEOROLOGY.

DISTRIBUTION OF PLANTS AND ANIMALS.

The *life* of the globe—that is, its vegetable and animal productions—constitutes its most important and exalted feature as a creation. All the

varied materials of which it is composed, all the complicated actions, reactions, and mutations to which they are subject, are humble phenomena compared with the production of the lowliest organism. This life is everywhere: the waters teem with it, the dry land from pole to pole is clad with it; nay, there is life within life, and perhaps there exists not a single plant or animal but becomes in turn an abode for others of more diminutive dimensions. Speculations as to the origin and generic classification of vegetable and animal life belong not to our subject. Geography views them simply as they exist, and endeavours to determine the laws which regulate their distribution.

Vegetables are regulated in their terrestrial distribution by conditions of soil, heat, moisture, light, height of situation, and various other causes; *in the waters*, by depth, heat, light, nature of bottom, and the presence of mineral and saline ingredients. Were it not for these causes, there is no reason why the tribes and genera of one region should not be identical with those of another—why the palms of India should not flourish alongside the oaks of England, the oaks of England with the pines of Norway, or these again with the dwarf birches of the arctic regions. As it is, the tropics have genera unknown to the temperate zone, and every advance poleward brings us in contact with new and peculiar species. Temperature in this case seems to be the grand regulating condition; and as this is effected by elevation, as well as by increase of latitude, we find the mountain-ranges near the equator presenting all the features of a tropical, temperate, and even arctic vegetation. Thus palms and plantains may luxuriate at their bases; then appear oranges and limes; next succeed fields of maize and wheat; and still higher, commences the series of plants peculiar to temperate regions. In temperate latitudes, though the variety of vegetation be less, similar phenomena present themselves. Besides these great climatic effects, there are others depending on soil, moisture, light, &c., which, though limited, are not less imperative. Thus, the southern slope of a hill is generally clothed with species distinct from those on the north; a limestone district presents a carpet of vegetation widely different from that of the clayey moorland: some tribes flourish in the moist valley, which would die on the open plain; some tribes thrive in the marsh, others on the dry upland; some luxuriate under the influence of the sea-spray, which would be instant destruction to others. But whilst most species are subject to these laws, there exists in the constitution of many a certain degree of elasticity which admits of their adaptation to a wider range—a beneficent arrangement, which permits man to extend through cultivation those grains and fruits upon which his subsistence so essentially depends. (For further and more minute information respecting the laws which regulate the dispersion and distribution of plants, see VEGETABLE PHYSIOLOGY.)

The animals which people the globe are subjected to somewhat similar laws of distribution. Some are strictly tropical, others confined to the temperate zone; while not a few are destined to find their subsistence wholly within the polar circles. Besides this general distribution, we find a more particular restriction to certain continents and tracts where peculiarities of soil, climate, and food seem to be the governing conditions. Thus, the elephant roams only in India, Burmah, and Africa; the ostrich in Africa; the rhea in the pampas of South America; the kangaroo in Australia; the reindeer within the arctic circle; the polar bear amid the snows of Greenland and Labrador; and so on, as will be more minutely shewn under ZOOLOGY. Similar laws are impressed on the life of the ocean. The 'right' whale, as it is termed, of the northern hemisphere, is a different animal from that of the southern; for 'the tropical regions of the ocean are to him as a sea of fire, through which he cannot pass, and into which he never enters;' while the sperm whale delights in warm water. The herring finds its chosen habitat in the Northern Sea; the oyster clings to a peculiar bottom, at a certain depth; the cod inhabits the same banks and shoals for ages; and a few fathoms of greater or less depth would be more fatal to many species of shell-fish than the dredge of the fisherman. As on plants, so on animals, altitude exerts a very decided influence; and we do not exaggerate when we affirm that a lofty mountain-range presents a more impassable barrier to vital distribution than the widest expanse of ocean. Though presenting a close analogy in the manner of their distribution, plants and animals differ in this respect, that many tribes of the latter—birds, fishes, and mammalia—make periodical migrations of vast extent; food and proper breeding-places being the objects of their search. These migrations must not be confounded with that adaptability of constitution which fits the horse, the dog, the ox, the sheep, the pig, and other domestic animals, to be the companions and supports of man in his onward possession of the globe. The one is but a change of place in search of food, under a congenial temperature; the other amounts to a constitutional change, irrespective of climatic influence.

Man, of all animals, has the widest geographical distribution. This he enjoys not only from the greater adaptability of his constitution, but from that superior intelligence which enables him to counteract the effects of climate by clothing, houses, fire, and the storing of provisions. It may be justly affirmed, therefore, that there is no region where man may not exist and carry on the purposes of life in a higher or lower degree of civilisation. Though generally regarded as a single species of a single genus, naturalists have divided mankind into several varieties, according to their more prominent physical features; and ethnologists, extending the subject according to minor features, language, and so forth, have subdivided these varieties into branches, tribes, and families. See ETHNOLOGY.

VEGETABLE PHYSIOLOGY.

THE science which embraces the study and investigation of the vegetable kingdom, is known by the name of BOTANY, from the Greek word *botané*, meaning an herb or grass. That department of the subject which explains the organisation and vital functions of plants, is called *Vegetable Physiology;* and that which recognises their arrangement into orders, tribes, genera, and species, according to their respective forms and qualities, *Systematic Botany.* The one relates to functions which are common to all vegetables, the other takes notice only of those structural peculiarities which serve to distinguish one species from another, and to enable the botanist to form these into natural and artificial groups. It is to the former of these departments that we now direct attention.

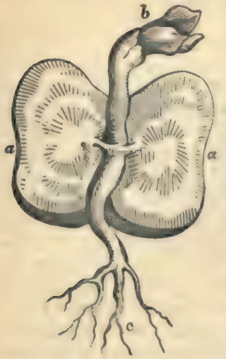
GENERAL ECONOMY OF VEGETATION.

Nature and Functions of Plants.—The simplest forms of life are observable in certain plants and animals, whose economy is limited to the absorption and assimilation of nutriment, and the power of reproduction; and the difference between these inferior forms is so trifling, that in them the animal and vegetable kingdoms seem to pass into each other. The absolute differences between plants and animals are indeed difficult to define, when they are to be applied to all plants and to all animals. In many cases, form and structure afford no decisive characters whereby we may separate the two kingdoms from each other; while phenomena usually regarded as pertaining to the animal kingdom are prevalent in the lower forms of plants, and indicate that no reliance can be placed upon their mode of life. In like manner, the chemical distinctions upon which much dependence has hitherto been placed, give way before increased knowledge; for cellulose and starch, long considered as peculiarly vegetable products, are now known to occur in animal structures. The locomotive power of many of the lower algæ is greater than that of many animal organisms; and even the spores, or seeds, of some algæ of more complex organisation, move about when freed from their parent, with an activity which appears truly animal, by means of the cilia with which they are provided. When the spore finds a suitable resting-place, its movements cease; and having thus exchanged its animal-like mode of life for one of a less erratic character, it becomes developed into a beautiful alga in all respects resembling its parent. The two classes, plants and animals, seem, as it were, to start from a common point at the base, the inferior forms bearing a certain similarity in structure and functions, which gradually disappears as we ascend in the scale of development.

Plants derive their food partly from the soil and partly from the air; and whatever they take must either be reduced to a liquid or to a gaseous state. The ultimate elements of which plants are composed are—carbon, oxygen, hydrogen, and nitrogen. Of these, carbon, which is a solid substance, is the principal; and as it is insoluble in water, it must be combined with oxygen, so as to form *carbonic acid gas*, before it can be taken up by plants. Oxygen is the next in abundance, and it is absorbed principally when combined with nitrogen, in the form of atmospheric air. Hydrogen is not found in a free state in the atmosphere, and therefore it can only be taken up by plants when combined with oxygen, in the form of water, or with nitrogen, as ammonia, in which last form it exists in animal manure. Nitrogen, though found in very small quantities in plants, is an important element, as it constitutes the principal ingredient in the *gluten*, which is the most nutritive part of corn and other seeds, and which is essential to the germination and nourishment of young seedling plants. Nitrogen also appears to be a principal agent in the production of colour in leaves and flowers, especially when they first expand. As oxygen is imbibed by plants in combination with all the other elements of which they are composed, it is not surprising that the plant takes up more of this gas than it requires; and, consequently, it has been furnished with a remarkable apparatus in the leaves, to enable it to decompose the carbonic acid and other gases which it has absorbed, and to part with the superfluous oxygen. Plants are thus found to improve the air by the removal of carbonic acid, which is injurious to animal life, and by the restoration of oxygen, which is favourable to it; and so to maintain a necessary equilibrium in the atmosphere, as animals are continually absorbing oxygen, and giving out carbonic acid. Light being essential to the decomposition of carbonic acid gas in the leaves, oxygen is not exhaled by plants during the night; but, on the contrary, a small quantity of carbonic acid gas escapes, and oxygen is absorbed. These processes have been called the *respiration of plants;* but they are very different from the respiration of animals.

Development of Vegetable Life.—This depends upon the concurrence of certain agents, the principal of which are—heat, air, moisture, light, and soil. No seed can germinate without the concurrence of the three agents of heat, air, and moisture; but in the *growth* of most plants, the agency of soil and light is also necessary. Every perfect seed contains the germ or embryo of a new plant of the same kind as the parent, and a portion of concentrated carbon and nitrogen, in the form of starch and gluten, laid up to serve as nutriment for the young plant, till its organs are sufficiently developed to enable it to seek food for itself. This nutrient matter is either contained in the tissues of the embryo's cotyledons, or laid up beside it in the seed, in the form of separate albumen. The seed is generally furnished with a hardened covering, in order to preserve it in an inert state as long as may be necessary. The common bean will afford a familiar example of the process of germination. As soon as it is put into the ground, it is acted upon by the influence of heat and moisture, which distend its tissues, so as to burst the external integument. The agency of the air is next required to

combine with the store of nutriment laid up in the seed, and to fit it for the purposes of vegetation.



The first organ which expands in the embryo of a young plant is the radicle, or root *c*. There is a small opening (foramen) in the covering of the seed, towards which the point of the root is always turned, in order that it may be protruded without injuring its soft and delicate texture. The radicle takes up water and air, and transmits the liquid thus formed to the other tissues. The nutritive substances laid up in the cotyledons, or seed-lobes (*a a*), become quite changed during the process of germination. The starch, which is insoluble in water, is rendered soluble by the action of a peculiar substance called ***diastase***, derived from the gluten, which acts as a ferment. This substance has so powerful an effect upon the starch as to render it instantly soluble, and thus nutriment is prepared for the use of the infant plant. The starch is changed into sugar; and when the store of starch and gluten has been exhausted, the plant is able to subsist by its own assimilating powers, at the expense of the air and the soil.

Heat, though essential to germination, is injurious, unless it be combined with moisture. A high degree of dry heat will parch seeds, and destroy their vitality; hence, when they are to be kept for food, it is not unusual to dry them in an oven, to prevent them from germinating. When combined with moisture, a very high temperature is not injurious to many kinds of plants, especially those of low organisation; for example, various species of plants inhabit the hot springs of Italy and the hot-water pools around the geysers in Iceland; while, on the other hand, certain lichens and mosses grow in the region of perpetual snow, where the temperature seldom rises to 32° Fahrenheit. Warmth is not only necessary for the germination of the seed, but also for the growth and after-development of the plant. In flowering plants the sap will not rise without a certain degree of heat. Cold will also check the development of the flowers and fruit, and even of the leaves, and will prevent the full flavour being attained by the fruit. The secretions of plants are diminished by cold.

Moisture must be combined with heat and air to render it useful to vegetation. An excess of moisture without heat, and combined with air, induces decay in seeds, instead of exciting them to germinate; and an excess of moisture is injurious even to growing plants, as it destroys the delicate tissue of the root spongioles.

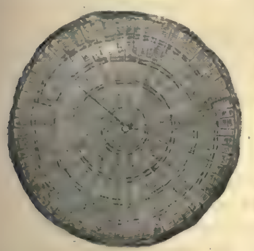
Air is essential both to the germination of the seed and the development of the plant. Without oxygen from the atmosphere, the carbon laid up in the seed cannot be made available for the use of the infant plant, as carbon in its concentrated state is insoluble in water, and requires to be combined with oxygen to convert it into carbonic acid gas. In like manner, air is essential through all the processes of vegetation; no wood can be formed, no seed ripened, and no secretions produced, without abundance of carbon; and this cannot enter the plant, even from the soil, without a constant supply of oxygen from the air.

Light is not required for the germination of seeds, but it is essential to the development of plants, as it occasions the decomposition of the carbonic acid contained in the parts exposed to its influence; without which the plant could not assimilate the carbon. Colour also appears to depend partly on light. Plants grown in darkness are of a sickly aspect, and are said to be ***etiolated***, or blanched.

In addition to the elements of which plants are principally composed, there is also found in their substance a quantity of inorganic matter, which differs according to the nature of the plant, and which appears to be derived solely from the soil. Plants require different kinds of inorganic food, according to their nature, and appear to possess the power of selection, as they only take the kind they need, though it may form but a very small portion of the soil in which they grow. Thus it is evident that any particular crop must in time exhaust the soil in which it grows of the requisite inorganic matters, unless they should be renewed by the addition of what are called mineral manures (see AGRICULTURE); and it is also clear that crops requiring another kind of earth may succeed in the same soil after it has become unproductive for the first kind of crop. Hence the necessity for what is called ***the rotation of crops***—that is, for letting crops of a different nature succeed each other in fields and gardens. Wheat, barley, rye, and oats are silica plants; pease, beans, and clover, lime plants; and turnips and potatoes, potash plants. Thus, these crops, from the difference in their predominant inorganic ingredients, are generally made to alternate with each other. In some soils containing a large amount of phosphates and other organic matters, the same plants may be cultivated successfully for a number of years.

Term of Vegetable Existence.—The longevity of plants differs according to their nature and the circumstances in which they are placed: thus, plants are ***annuals***, which grow only one season, and die as soon as they have ripened their seed—***biennials***, which generally last for two years—or ***perennials***, which last for several years. Trees and shrubs, which have ligneous or woody stems, are destined to remain undecayed for years. The term ***shrub*** is applied to those woody plants which branch out from near the root, and seldom attain a great height; while ***trees*** have, generally speaking, only one stem or trunk proceeding from the root to a considerable height before it divides into branches. The length of time which trees live depends in a great measure on the situations in which they grow. The age of trees was formerly calculated by their diameter, or by the number of concentric circles or layers in the trunk; but both these modes are now found to be often fallacious. According to the first, it was supposed that if a tree attained the diameter of a foot in fifty years, fifty years should be counted for every foot it measured in diameter; and thus it was supposed that the great baobab tree, found by Adanson on the banks of the Senegal, which measured nearly thirty feet in diameter, must have been about 6000 years old, or coeval with the world itself. It is found, however, that the

baobab, like all soft-wooded trees, grows rapidly, and attains an enormous diameter in less than a hundred years. The mode of counting by concentric circles only applies to exogenous trees, and even with them is very uncertain. A warm spring, which sets the sap early in motion, followed by weather cold enough to check vegetation, will give the appearance of two layers in one year, as the recommencement of vegetation will have the same appearance as a new layer in spring. In many trees, such as the oak, for example, a second growth often takes place after midsummer; so that even a third layer is occasionally formed in the course of six months. On the other hand, it is possible that a moist warm winter, by keeping an evergreen tree growing the whole year without any check to vegetation, might give the appearance of only one layer to the growth of two years. Notwithstanding these anomalies, practical men find counting the concentric circles of a tree the best mode which has yet been discovered of ascertaining its age, as in northern countries only one growth is made in the course of a year. The accompanying figure represents a section of an exogenous or outside-growing stem five years old, having the pith in the centre, a cylindrical layer for every year of the growth, the bark on the outside, and the medullary rays passing from the centre to the circumference.



DISTRIBUTION OF PLANTS.

The geographical arrangement of the vegetable world is influenced by conditions of soil, heat, moisture, light, altitude of situation, and various other causes; for, did they flourish independently of these conditions, then there were no reason why the vegetation of one part of the globe should differ from that of another. The flowers, shrubs, and trees which adorn the plains of India, are not the same as those which clothe the valleys of Britain; and these, again, are totally different from the scanty vegetation of Iceland or Spitzbergen. Each species is, nevertheless, perfectly adapted to the conditions under which it exists, and finds in its native situation all the elements required for its growth.

In a state of domestication, however, many species exist in regions far beyond the limits of their original distribution. Our cultivated useful plants are of this kind; as, for example, the potato, which is a native of tropical America, and is of the highest utility in Northern Europe. In South America, the warm climate enables it to propagate by the seed; hence in that region its tubers are small and insignificant; but in Europe, where the climate is unfavourable to the production of the plant from seed, it propagates by the tubers, which are consequently enlarged, so as to contain a store of nutriment for the young plant, before its stem and leaves be sufficiently developed.

The *habitats* of plants—that is, the situations in which they naturally thrive best—are generally distinguished as follows: *Marine*, when the plants float upon, or are immersed in, salt water, such as sea-weeds; and *maritime*, when they grow by the sea-shore, or in places exposed to the influence of the sea-breeze. *Aquatic* is the general term for fresh-water habitats; and these may be *lacustrine*, that is, growing in lakes—*fluviatile*, in rivers—or *palustrine*, when in marshes or wet meadow-lands. Plants are also distinguished as growing in open pastures, in cultivated lands, woods, mountainous parts, and in caves, mines, and other underground excavations. The term *epiphyte* indicates that the species grows upon others without deriving from them the elements of nutrition; and *parasite*, that it adheres to their surface, enters their tissue, and directly extracts its nourishment. Examples of epiphytes are seen in numerous species of tropical orchids, and parasites in such plants as the mistleto, dodder, and Broom-rapes. The range of habitat is that extent of the earth's surface over which a plant is distributed by nature. The terms maritime and alpine, for example, are general in their application, and refer to all plants which grow by the sea-side or on mountains; but the plants which flourish on the sea-shores of Great Britain are not the same with those on the coast of Africa; nor are these, again, identical with the maritime vegetation of Chili. The geographical range of any plant conveys a more special idea, and embraces only that particular tract over which the species extends. This range is circumscribed by conditions of temperature, light, and elevation above the sea, and does not, as might be supposed, depend very closely upon belts of longitude, by which temperature is generally indicated. Thus, nearly all the beautiful Pelargoniums and Mesembryanthemums which adorn our green-houses are natives of a limited space near the Cape of Good Hope, as are also many of our most beautiful bulbs. The curious Stapelias, that smell so much like carrion, are found wild only in South Africa. The different kinds of Eucalyptus and Epacris are restricted to Australia. The Umbelliferous and Cruciferous plants spread across Europe and Asia; the Cacti are found in tropical America; and the Labiatæ and Caryophyllaceæ are seldom found beyond Europe. The peculiar ranges and centres of vegetation, as they are termed, cannot be sufficiently understood, however, without a knowledge of the different tribes and classes of plants, the consideration of which forms the subject of next paper—SYSTEMATIC BOTANY.

Soil exercises less influence on the distribution of plants than is usually ascribed to it, though there can be no doubt that on its power of absorbing and retaining heat and moisture much of the luxurious growth of vegetables depends. They will grow to some degree in almost any soil, as the bulkier ingredients—clay, lime, and sand—always predominate; but a proper proportion of these earths is necessary to perfect vegetation, and many plants will not continue healthy and propagate unless supplied with other elements, such as potash, soda, and various metallic salts. For this reason, the natural vegetation of a limestone country differs from that of a retentive clay; while the plants which cover sandy downs are different from those of the alluvial valley. Moisture, which is indispensable to the existence of vegetation, also exercises great influence in its natural distribution. Very dry regions are deficient in vegetable forms, while their luxuriance in tropical countries is connected with great heat and moisture. The plant

which roots in the parched sand is furnished with leaf-organs to absorb moisture from the atmosphere, and retain it; while in a wet situation these organs would become diseased, and rot away; so, in like manner, a marsh-plant, whose spongioles are its main organs of sustenance, would perish were it removed to an arid soil. The organic structure of such plants forms a limit to their distribution; and the same may be said of the Salicornia, Salsola, *Lepigonum marinum*, &c., which live only when exposed to the salt spray of the ocean.

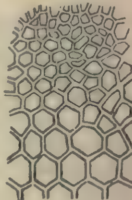
Heat and light are perhaps the most manifest agents in the distribution of vegetable life. The luxurious growth of the tropical jungle is the direct result of warmth and moisture, just as the barrenness of Nova Zembla is the effect of piercing cold; yet both situations are inhabited by plants which enjoy the conditions peculiar to their existence. No conditions of mere soil, or light, or moisture, could make the palms, tree-ferns, and jungle-flowers of India flourish in Great Britain; so neither would our oaks or pines flourish in Iceland, unless we could provide for them that temperature and seasonal influence necessary to their healthy existence. Light, though it acts most powerfully on the colours and blossoms of plants, is in some measure an element in their geographical arrangement. The northern side of a hill may sometimes be as green, but it never will be so flowery as the southern. The more free the exposure, the more readily will most plants also blossom, and yield a rich fruit. So well is this understood in the grape-countries on the Rhine, that the right bank of that river, which faces the sun, is reckoned to be much more valuable than the left, and commands a higher price for its wines.

Altitude, or elevation above the ordinary sea-level, also exerts an obvious influence on the distribution of vegetable life: it is equivalent to removal from a tropical to a temperate region, or from temperate latitudes to the arctic circle. For every hundred feet of ascent, there is a proportional fall of the thermometer; so that, at the height of 5000 feet in the latitude of Britain, and 16,000 at the equator, we arrive at the region of perpetual snow. This intimate relation between altitude and decrease of temperature accounts for the fact, why the base of a mountain may be clothed with the vegetation of tropical India, the sides with that of temperate England, and the summit with the mosses and lichens of icy Labrador. 'We may begin the ascent of the Alps, for instance, in the midst of warm vineyards, and pass through a succession of oaks, sweet chestnuts, and beeches, till we gain the elevation of the more hardy pines and stunted birches, and tread on pastures fringed by borders of perpetual snow. At the elevation of 1950 feet, the vine disappears; and at 1000 feet higher, the sweet chestnuts cease to thrive; 1000 feet farther, and the oak is unable to maintain itself; the birch ceases to grow at an elevation of 4680; and the spruce-fir at the height of 5900 feet, beyond which no tree appears. The *Rhododendron ferrugineum* then covers immense tracts to the height of 7800 feet; and the herbaceous willow creeps 200 or 300 feet higher, accompanied by a few saxifrages, gentians, and grasses; while mosses and lichens struggle up to the imperishable barrier of eternal snow.'

The circumstances which facilitate the dispersion or migration of plants, are not unconnected with the causes which limit their geographical distribution. Many seeds drop from the parent stalk, spring up into new series of stems, which in turn give birth to another race of seeds, and these again to another circle of vegetation. Thus, any species of plant would spread from a common centre till arrested by the influences which limit its range of habitat; and this mode of dispersion no doubt frequently occurs. In most plants, however, the seeds are small and light, and easily borne about by the winds: some are downy, and furnished with wings or hairs, while others are ejected from their carpels with considerable force. All these appendages and peculiarities are evidently intended to facilitate their dispersion, which is further assisted by rivers, lakes, and tidal currents, by the wool of animals, the droppings of birds, and the economical pursuits of man, whether accidental or intentional.

STRUCTURE OF PLANTS.

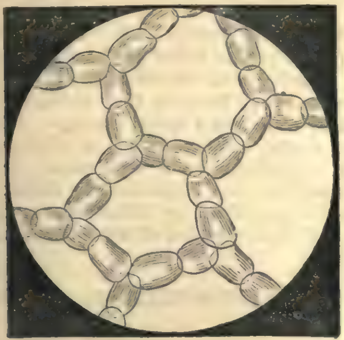
In order to explain the varied phenomena of plant-life, we must revert to the elementary tissues of which the various organs are composed. It is in these tissues that the processes of growth and multiplication, of individual development and of reproduction, can alone be accurately traced. Vegetable Histology limits itself to such investigations. If we cut a thin slice from the leaf or succulent stem of a plant, and place it under the object-glass of a microscope, we shall find it to present the general appearance of a web or tissue, more or less of a honeycomb form, as represented in the wood-cut (*a*). If more carefully examined, it will be found that the apparent meshes of the network are not hollow spaces in a homogeneous mass or membrane, but that each has its own envelope—is, in fact, a minute bladder or vesicle, or elongated tube, as the case may be; and that the whole mass of tissue is formed by the aggregation of such vesicular or tubular bodies held together by means of an imperceptible layer of intercellular matter, which causes the contiguous cell-membranes to cohere. In the tissues of plants there is an infinite variety, both as regards the form and arrangement of their elementary bodies, but all may be reduced to three distinct types of structure, to one or other of which every modification can be referred. These are distinguished as the *cellular*, *woody*, and *vascular* tissues.



a, Cellular tissue.

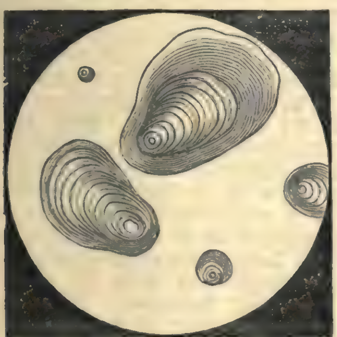
Cellular tissue (*Parenchyma*) may be said, in general terms, to form the soft and succulent parts of plants—as, for example, the pith of trees, the delicate central tissue of Papyrus, shewn in the following figure (*b*), and the soft parts of our esculent vegetables and fruits. It is composed of minute bladders or vesicles, which are called *cells*, which have their walls composed of a chemical substance called cellulose. Cells are seldom so large as to be visible to the naked eye, but are readily seen under a compound microscope. They usually consist of a pellucid membrane, and contain a formative protoplasm in their interior, with nuclei and nucleoli, which give origin to new cells.

Starch, gum, sugar, oil, resin, colouring matter, air, crystals, and other nitrogenous substances, are



b, Papyrus: pith-like tissue, composed of cells arranged in form of a network, so as to leave large intercellular spaces (*ad nat.*).

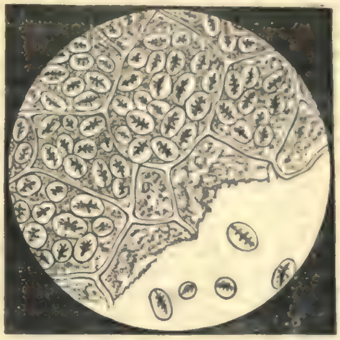
also found in the cells of plants. Starch is a very abundant substance in cells, serving purposes of nutrition, and may be readily seen by placing under the microscope a thin slice of potato upon which a drop of tincture of iodine has fallen; this induces a beautiful blue colour in the starch-granule, and is a constant test for the occurrence of starch. Starch usually occurs in the form of minute grains, many of which are contained in each cell. Their form is often constant and characteristic in certain plants—for example, the very minute angular starch-granules of rice are quite different from those of the other cereal grains, which, again, are easily distinguished from those



c, Starch-grains of Potato (*ad nat.*).

of the potato, shewn in the above figure (*c*); while those of leguminous plants have a somewhat common character (*d*). The peculiarities of starch-granules have been successfully employed in detecting adulterations of food and drugs, and for other purposes of practical utility.

The cell in many cases displays a thickened opaque wall and an empty cavity within. This arises from the deposit of woody matter on the interior surface of the cell-wall, which is seen in the hard stone of the cherry and in the shell of the coco-nut, both of which consist of cellular tissue equally with the softest parts of their respective fruits, and owe their solidity to the indurated woody matter. Instead of having the whole inner surface of the cell covered in this way, the deposited matter may be so arranged as to cover



d, Lentil: cells of seed containing Starch-grains (*ad nat.*).

certain parts only: it is often deposited in the form of rings or spiral coils; and in the latter case gives rise to the beautiful spiral cells seen in the

e, Spiral tissue from the root of an Epiphytal Orchid (*ad nat.*).

leaves and roots of epiphytal orchids (*e*), and in the leaves of bog-mosses (*Sphagnæ*).

With respect to their general form, cells are exceedingly variable, and are usually greatly modified according to the position in the plant which they occupy. They very commonly present the hexagonal appearance represented in the woodcut (*a*); but in the bark and young stems, as well as in roots and other parts, they often assume an oblong form (fig. *e*); sometimes resembling the bricks of a wall set on end, and thus indicating the manner in which plant-structure is built up, as it were, by separate cells cemented together.

The rounded or spherical form may be regarded as the normal form of the cell, the two modifications to which we have alluded arising from the pressure of spherical or oval cells in contiguity, or special modifications intended to fit them for their place in the structure. In many cases, however, we find cells of a very different form, whose modifications obviously arise from certain special functions which they are designed to perform. The pith-like substance of the rush, used as wick for 'rush-lights,' consists of cells of a most beautiful stellate form; the free cells or spores of certain

algæ are covered with cilia, which give them locomotive power; the cells of hairs are elongated, and often much branched; and the cells of unicellular algæ, such as the Desmideæ and Diatomaceæ, often display the most exquisite symmetry, both in outline and in the elaborate sculpture of their surface. The cotton hair, which is a cell in peculiar condition, presents the form of a flat twisted band with a thickened margin, a character which is retained by it after it is dressed, spun, and woven into cloth, and even after that cloth has been worn to rags, reduced to pulp, and remanufactured into paper.

In the pulp of leaves and fruit, and in the cellular tissue of the bark, there are frequently cavities found among the cells, which are of several kinds. Those called *receptacles of secretion* are formed for the reception of the oils and other fluids secreted by plants; as, for example, the fragrant oil in the myrtle and the orange, and the turpentine in the pine and fir tribe. Other similar cavities, called *air-cells*, contain oxygen nearly in a pure state, and are called *intercellular spaces*. All these cavities have no distinct membrane to inclose them, but are surrounded by what may be called a wall of cells, which form part of the cellular tissue. If the stem of the common *Hippuris*, or mare's-tail, or the leaf-stalk of a water-lily, be cut across, a beautiful arrangement of these intercellular spaces will be displayed, and the manner in which they are formed by the peculiar arrangement of the plant's cells is shewn in wood-cut *b* (page 69).

Cellular tissue readily decays when the parts composed of it fall from the plant. In leaves, the pulpy parts disappear first, leaving behind the outer cuticle and the nerves or veins, which are of firmer texture; the latter, indeed, being composed principally of woody tissue, the tubes of which have been filled with earthy matter during the process of vegetation, decay very slowly. Those parts of a plant which nature seems to have intended not to be of long duration—such as the fleshy parts of the leaves, the flowers, and the fruit—are composed entirely of cellular tissue of loose texture.

Woody Tissue (*Pleurenchyma*).—The stems of trees and of flowering-plants in general possess a tenacity not found in the leaves and flowers. This is mainly due to the presence of woody tissue, which consists of minute spindle-shaped tubes lying closely together, and overlapping each other at the ends. The strength of these tubes is mainly due to the deposit of ligneous matter on their inner surface. The value of many plants employed in the arts depends upon the abundance of this tissue: when separated from the softer tissues of the stem and leaves by maceration, it forms the fibre of flax, hemp, jute, Chinese grass, and other textile substances well known in commerce. In cone-bearing plants, such as the Scotch fir, the woody tissue is very peculiar, each tube exhibiting a series of round discs with a central dot. By carefully studying the peculiarities in such tissues, the sources of unknown timbers may often be determined. In most pines there is a single row of discs on each tube, while in others a double row of opposite discs is observed. In the Araucarias of the southern hemisphere, the discs are angular, and are arranged alternately in several rows; and in the yew, the tube has beautiful spiral markings as well as minute discs. Such characters are invaluable to the student of vegetable palæontology.

Vascular tissue has been divided by modern botanists into three kinds—namely, *vascular proper*, *pitted*, and *laticiferous*. Vascular tissue consists of cylindrical tubes of great delicacy and thinness, called *spiral vessels* and *ducts*. *Spiral vessels* are so called because they contain delicate fibres coiled round in a spiral manner. They are of a light elastic nature, and their fibres, though coiled up naturally like a cork-screw (see fig.), may be unrolled to a considerable extent. If a leaf-stalk of a geranium or strawberry be cut half through, and then doubled down first on one side,

Spiral Vessel.

and then on the other, and the two pieces be then carefully and gently drawn asunder, the transparent membrane will break, and the spirals will unroll so as to appear, when seen with the naked eye, like fine hairs between the two portions of the leaf-stalk. Spiral vessels prevail in leaves and flowers, and are found, though more sparingly, in the young greenwood of trees and shrubs; but rarely in the old solid wood, roots, or bark. They are few in coniferous trees; but abundant in palms and their allies. In ferns and the club-mosses they occur occasionally, but are usually replaced by a peculiar kind of vascular tissue, called the *scalariform* tissue, from the ladder-like appearance on the angular vessels, caused by bars of fibre in their interior; the other cryptogamous or flowerless plants have no vascular tissue.

Pitted tissue, sometimes called *dotted ducts*, consists of tubes which, when viewed by transmitted light, appear full of holes. This depends on the incrusting matter or cellulose inside being unequally deposited over the surface of the membrane, and thus leaving uncovered spots at various intervals. The dotted ducts are larger than the vessels of the other tissues. They frequently exhibit contractions at intervals, which give them a jointed or bead-like appearance. In such cases, they seem to be formed of dotted cells placed end to end, with the partitions between them obliterated, so as to form continuous cylindrical tubes. Laticiferous tissue consists of tubes which are distinguished from all other kinds of tissue by being branched. They are filled with a fluid called *latex*, of a granular nature, often milky or coloured, and exhibiting movements. This milky fluid abounds in the India-rubber and gutta-percha plants, and is seen to exude in abundance from the dandelion when its leaves or stalks are wounded. The fluid, in many plants, contains a large quantity of caoutchouc; it is bland and nutritious in the cow-tree of the Caracas, but in many other plants narcotic and acrid.

Multifarious as are the modifications of the tissues of plants, and the cells and vessels of which they are composed, all have a common origin, all are modifications of the *cell*. The plant begins its existence as a cell, and its whole course of development may be said to be the evolution of cells. The process of cell-development, or cytogenesis, thus explains the whole phenomena of plant growth and reproduction. To the investigation of this subject,

therefore, the attention of vegetable histologists has of late years been specially directed, and the results have appeared in the form of certain theories which have given rise to much angry discussion. There appear to be four modes in which vegetable cells are multiplied—namely, by nuclei, by division, by gemmation, and by conjugation.

GENERAL INTEGUMENT AND ITS APPENDAGES.

Submerged plants have the cells of their leaf-tissue directly exposed to the action of the surrounding water; but land-plants usually have all their organs invested in an epidermis or skin, which regulates transpiration, and prevents their tissues becoming dried up. The surface of this epidermis, again, is covered by a very thin structureless layer, called the cuticle. The epidermis is composed of cellular tissue; but the cells are pressed closely together, and flattened, and they are often filled with air instead of water. The use of the epidermis is to retain a sufficiency of moisture in plants; for should the delicate membrane of which the cells of their tissue are composed become so dry as to lose its elasticity, the different organs would be unable to perform their proper functions. On this account, its thickness is curiously adapted to the conditions under which a plant grows. Plants of very hot countries are supplied with three or even four layers of dense external tissue, in order that the moisture may be retained, notwithstanding the excessive heat and dryness of the climate. But it is necessary that the tissues of plants should not be shut out from the free action of the atmosphere, whence a large proportion of their food is derived. They are therefore provided with peculiar breathing-pores, or *stomata*, by which air and fluid enter, and from which fluid transpires. In mosses, where the leaves usually consist of a single layer of cells, stomata are confined to the fleshy base of the fruit; but in flowering-plants they chiefly occur on the under surface of the leaf; and this is especially the case in many evergreen shrubs, which are thereby enabled to benefit by the moist exhalations from the soil and herbage beneath, without suffering from a scorching sun. This law is reversed where the habits of the plant require such an adaptation. Water-lilies and other plants whose leaves float on the surface of the water or lie flat on the soil, have no stomata on their under surface, but are supplied with an increased number on their upper surface, which alone is exposed to the action of the atmosphere. The following calculation of the number of stomata in the leaf of the royal water-lily, will serve to indicate the extremely minute size of these bodies and the great numbers of them required by plants: each stomate measures the $\frac{1}{300}$th part of an inch in diameter; one square inch of surface contains 139,843 stomata; so that one ordinary sized leaf of this plant, with a surface of 1850·08 square inches, contains upwards of twenty-five millions of stomata (25,720,937).

Hairs are minute prolongations from the epidermis, and are found upon almost every part of plants. Sometimes they cover the whole of the leaf, and at others they are only found on one surface. They are described in general terms as downy, silky, hirsute, bristly, ciliate, &c. according to their aspect and mode of arrangement. The hairs of plants are exceedingly variable in size and form, and are either unicellular or multicellular—consisting of one or of many cells. In either case, they may be simple or branched. There are branched unicellular hairs in Cruciferæ, and beautiful stellate hairs in many plants. The sting of the nettle is a modification of the hair, being a conical tube with a basal bulb, filled with irritant fluid, which shews singular movements under the microscope. The tube is sharp-pointed, and surmounted by a little curved knob; when the plant comes in contact with the hand, this knob is knocked off; the sharp point which it protected now penetrates the skin; and the pressure upon the conical sting causes the irritant fluid which it contains to be poured out into the wound. The whole phenomenon is strikingly similar to the mode of action of the animal sting.

Glands.—Although some have stated that there is no true process of secretion in plants analogous to that of animals, still the latest researches seem to indicate that such a process does exist, and that it is performed by special organs—usually modifications of the epidermis itself or of its appendages. Thus, in the Cinchonas of South America, we have conical glands, which pour out a gum-resinous matter on their free surface. The same kind of glands are found in the bedstraws of our hedgerows. The honey of many flowers also appears to be a true secretion, poured out upon a free surface of the tissue by special cells, which are not analogous to the fat-cells of animals, to which the so-called vegetable secretions have been likened.

Besides the above-mentioned organs, there are prickles, thorns, and spines. *Prickles* may be called hardened hairs, as they are merely indurated expansions of the epidermis, without any woody fibre; and they may be detached from the branch which bears them without laceration. Examples of prickles are well seen in the rose and bramble. *Thorns* differ from prickles in being formed partly of woody fibre; and they cannot be detached from the branch which bears them without lacerating its vessels. They have their origin in buds, and are the result of an arrestment of development, being formed instead of leaves and branches. Examples in hawthorn and sloe. *Spines* resemble thorns in every respect, except in being found on the leaves and stems of herbaceous plants; while thorns only grow on the trunk and branches of woody plants. When spines grow on leaves, they are always found on the veins which are extensions of the woody fibre. Example, holly.

ORGANS OF NUTRITION.

The organs of nutrition are the root, the stem and its branches, and the leaves; and of these organs, the root and the leaves, or some modification of them, exist in every flowering-plant, as the vital functions cannot be carried on without them.

The root (*radix* in Latin) is commonly defined to be that part of a plant which attaches itself to the soil where it grows, or to the substance on which it feeds, and is the principal organ of nutrition. Exceptions to this definition occur, as in the case of some plants which grow floating loosely in water, as duck-weed, as well as in the case of others having no root at all. As the nourishment of a plant is derived from the earth, the root is that part which grows in an opposite direction to the stem, and is buried in the ground. It is the

descending axis, while the stem is the *ascending*. The more common form is the fibrous root as seen in grasses, the fibres being terminated by loose cells or spongioles, which are the absorbent points. But the main root is often thickened into a tap-root, giving off secondary fibres—globe-shaped, in the turnip—conical, or tapering gradually from the collar to the attenuated fibre, in the carrot—fusiform, or tapering at both ends, in the radish—abrupt, where the lower end appears as if cut off, in the devil's bit scabious. In the dahlia, the roots branch off in a fasciculate manner; while in the orchis (*O. mascula*) they are tuberous, being in the form of globe-shaped bodies filled with starchy matter. The so-called tuberous roots of the potato are merely underground stems, from the circumstance of their having eyes or buds from which branches will spring.

The crown, collar, or life-knot, as it is variously called, is that part which lies between the stem and the root. It is the most essential portion of the whole; for if it be removed, or seriously injured, the plant will die; whilst the small fibres or rootlets, although an essential part of a plant, may be destroyed at pleasure, so long as the crown remains, for it readily reproduces them. When it is of a slender make, it dries up as the seeds ripen, and the plant soon dies, as seen in the corn-poppy, mignonette, and other annuals.

Roots have a remarkable tendency to grow downwards, or in the direction of the earth's centre; and from experiments, it seems not unlikely that this tendency is to some extent an effect of gravitation. The precise direction, however, is very much influenced by the condition of the soil. Both root and rootlets extend as if in quest of food, and will penetrate sidewise or obliquely to great distances. Though the root and stem differ in many respects, yet there are cases where it becomes difficult to distinguish between them. Some species of palms send down aërial roots for the purpose of strengthening their stems, and the same are seen very remarkably in the screw-pines and banyans. Many herbaceous plants send out roots in a similar manner when they are earthed up; and trees which grow in unnatural situations, as on a wall or bare rock, send down roots in quest of soil and moisture, which afterwards take the appearance of stems. The willow, maple, gooseberry, and some other plants, may have their roots converted into stems by reversing the plants, and burying the tips of the shoots in the earth, so as to leave the roots in the air. In this case, the branches will soon send out fibrous roots from the joints which have been buried in the earth, and the fibrous part of the old roots withering, the roots themselves will gradually assume the character of branches.

The Stem.—When a plant shews itself above the ground, it evidently manifests a strong tendency to the light. Light, in fact, is essential in bringing it to maturity, and in giving the green colour to its leaves. The stem, with a few exceptions, is always above ground. It is divided from the root by the part called the crown or collar. The space between the collar and the first branch is termed the bole or trunk. The stem of grasses, corn, and reeds, receives the name of culm; the stem of such flowers as the primrose, dodecatheon (see fig.), and the daisy is undeveloped;

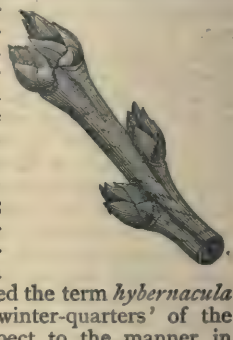
hence they are called stemless (acaulescent); the stalk upon which the flowers are borne being termed the scape, or flower-stalk; the running-stem, as in the strawberry and cinquefoil, is termed a runner; a shorter runner that does not root, as in the house-leek, is termed an offset; and a small stem proceeding laterally from a root or stool, a sucker.

The stem assumes many forms and characters as to bulk, structure, position, place, and duration. It appears as a corm (sword-lily, 1); a

1 2 3 4

bulb (the onion, 2); a culm (reed, 3); or as a woody trunk (the oak, 4). When a trunk bears permanent or perennial branches, the plant is termed a tree; when permanent branches arise, not from a distinct trunk, but from near the root, the plant is termed a shrub; and when the whole stem is not woody, and dies down every year, at least as far as the crown of the root, the plant is termed a herb. Trunks which increase by successive layers of new wood on the outside of the old, as the ash and beech, are termed *exogenous;* those which increase by the addition of fibrous matter in the centre, as the palms, are styled *endogenous;* and those which do not sensibly increase in thickness, and are formed by the adhesion of the leaf-stalks as they spring from the growing point, as the tree-ferns, are said to be *acrogenous.* (See SYSTEMATIC BOTANY, p. 108, figs. *b*, *a*.)

Buds, which have various forms, consist of the young shoots, leaves, or flowers, and proceed from what is called the *axil* of a leaf. They are usually formed either early in summer or in autumn, and are so contrived as to preserve from injury the delicate structure within. The outside is composed of tough scales, which are frequently covered with a gummy resin; and they are internally protected by a downy substance interposed between



the leaves. Linnæus applied the term *hybernacula* to leaf-buds, being the 'winter-quarters' of the young branch. With respect to the manner in which the leaves are arranged and folded in the bud, which is termed *vernation*, they may be simply placed in apposition, as in the mistleto; plaited, as in the palm and birch; doubled, as in the rose and oak; embracing, as in the iris and the sage; double embracing, as in valerian and teasel; rolled inwards, as in grasses; rolled outwards, as in rosemary, primrose, &c.; rolled lengthwise, breadthwise, rolled from the tip to the base, or wrapped round the stalk.

Leaves.—Leaves, from their number, position, and delicacy of organisation, are designed to effect an important office in the vegetable economy. Springing from the branches, and exposed in profusion to the atmosphere, they perform the functions of a breathing-apparatus analogous to that of the lungs or gills of animals. A similar purpose at least is designed; for the sap of plants, like the blood of animals, requires to be exposed to the atmospheric influence, in order that it may be suitable for nutrition. This purpose is accomplished by the agency of the leaves, to which the sap, on rising from the roots through the stem and branches, is propelled or attracted, and there both air and light exercise their beneficial influences. Leaves are thus indispensable to the growth of plants, and care should be taken not to injure them; for defoliation, either naturally or by art or accident, instantly arrests the growth, and the failure or diminished expansion of foliage is a certain sign of debility.

A leaf consists generally of two parts—the

petiole, or leaf-stalk; and the lamina, or blade. Sometimes, however, as in the rose tribe, stipules (*s*, *s*) are attached to the base of the petiole. The leaf-stalk (*a*) is that part which connects the leaf with the branch, and at the base will be found slightly hollowed, in which a bud rests. Sometimes the leaf-stalk is wanting, and thus the leaf is said to be sessile. In some Australian acacias and eucalypti, the petiole is flattened, and occupies the place of the leaves. Such petioles are called *Phyllodia*. The lamina, or broad part of the leaf (*b*), is frequently of a different colour on the under side. This is exemplified in the common silver-weed (*Potentilla anserina*), the leaves of which are hoary on the lower side, and green on the upper. Leaves are either *deciduous*—falling in autumn—or *evergreen*, lasting till the following season. Their forms are exceedingly varied—being *simple* or *compound;* and these, again, are distinguished as oval, lanceolate, cordate, hastate, sagittate, pinnate, &c.

An important character is afforded by the *venation* of leaves—that is, the arrangement of what are called their veins. In exogenous or dicotyledonous plants—as our timber trees, for example—the leaf is furnished with a strong midrib, from which secondary veins diverge, at regular distances; and these, again, branch off into still smaller tertiary veins, whose ramifications form a reticulation or network in the leaf. In endogenous or monocotyledonous plants—as grasses and lilies—there is usually no distinct midrib, but several primary veins, which originate in the base of the leaf, and proceed to its apex, being parallel throughout. In many tropical endogens, however, there is a distinct midrib, from which secondary parallel veins diverge on either half of the lamina. In acrogens or acotyledonous plants—as ferns—the veins are usually arranged in a forked manner.

The veins of leaves consist of woody tissue, accompanied by spiral vessels, the interspaces being filled up with the softer parenchyma, or cellular tissue. By maceration, the latter may be made to disappear, so as to leave merely the veins. In aquatic plants, there is a strong tendency to non-development of the parenchyma; thus, in many of the aquatic crow-foots, the submerged leaves consist almost wholly of veins, while the floating ones are entire; but the most remarkable instance of this occurs in the *Ouvirandra fenestralis*, a water-plant introduced to our hot-houses from Madagascar, whose leaves are so destitute of parenchyma, that they are, in fact, beautiful lattice-like skeleton-leaves. The leaves of the royal water-lily are perforated with minute holes at regular intervals, and large open spaces occur in the leaves of *Monstera* and *Dracontium*.

With regard to the manner in which leaves project from the branches, and their distribution over the woody cylinder to which they are attached, every possible variety may be observed. They may be opposite—that is, two leaves growing on either side of the branch, the one directly opposite to the other; alternate, when one leaf springs out on one side of the branch, and another on the opposite side, a little above it, and so on; whorled, or *verticillate*, when a number of leaves grow round the stem from a common knot or joint, as in the bed-straw. The distribution of alternate and opposite, however, is not regular; for in some instances it will be found that the leaves on the lower part of the stem are alternate, whilst those on the upper are opposite. There are many plants which have few or no leaves, but whose stems are much dilated, presenting a large superficies of parenchymatous exterior to the air and light—as, for example, in the cactuses.

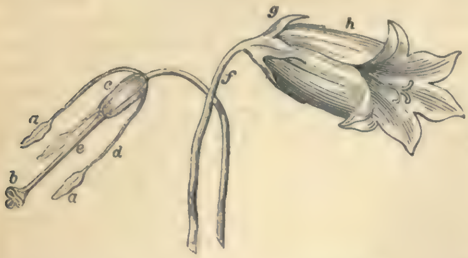
Green is the most general colour of leaves, but some are red, or purple, or yellow; some appear nearly white, in consequence of being clothed with short woolly or silky hair. Leaves are often variegated, in consequence of the non-development of chlorophyll in the cells of certain parts. They differ much in substance and structure: some are immensely thick and fleshy, as those of the genera *Aloe* and *Agave;* others remarkably thin, as those of the beech.

ORGANS OF REPRODUCTION.

The organs of reproduction are the flower, fruit, and seeds; and these, or some modification of them, exist in every perfect *Phanerogamous* or flowering-plant.

Flower.—A flower consists of several distinct parts—the calyx, corolla, stamens, and pistil. A flower is essentially constituted by the presence of the last two, which are the sexual organs. When there is only one of these present, the plant is termed unisexual; but more commonly these organs are both present in the same flower, which is in this case termed hermaphrodite. In some instances, although the same plant bears both

male and female organs, it is not hermaphrodite, as these organs occur in different flowers; in others, again, the male and female flowers exist only on different plants. Lastly, male, female, and hermaphrodite flowers are sometimes found together, either on the same or on different plants. Sometimes the male or female organs alone, protected by a small scale, constitute the flower; but in general they are surrounded and protected by the corolla and calyx, which are called the floral envelopes. All these are commonly borne on a stalk called the peduncle (from *pes, pedis*, a foot), which, expanding at its extremity, forms the receptacle, or torus, upon which the whole of the



a, a, anthers; *d*, filament; *b*, stigma, or summit of pistil; *e*, style; *c*, ovary, or seed-vessel; *f*, peduncle; *g*, calyx; *h*, corolla.

parts above mentioned are supported. What is called the berry in strawberries is nothing more than the fleshy receptacle bearing the carpels on its surface.

The *calyx* (from *kalyx*, the cup of a flower) is the external leafy envelope surrounding the corolla, and in which the latter rests as in a cup. Sometimes it is entire, but more frequently it is divided into segments, called *sepals*, which are more or less separated from each other. It is most commonly green, but in some flowers it is coloured.

The *corolla* (a little crown) is the conspicuous highly coloured part of the flower or blossom, and consists of several divisions or leafy parts called *petals*, which are articulated at the base, and consequently fall off at the earliest manifestations of maturity or decay. The variety of tints in the flowering part of plants is remarkable. The lower part of the single petal of a corolla is called the claw, and the broad part is called the limb. The corolla is frequently furnished with certain secreting organs, attached to the throat or the base of the petals, called nectaries. In some plants the corolla is absent.

Stamen (a distaff).—Within the beautiful corolla are observed several small filaments, arranged in a circle around the central parts, and bearing on their summit little oblong bodies; which are usually apparently covered with particles of a fine coloured matter like dust. These are the male parts of reproduction, the stamens, which are always next to the petals—that is, between their base and the base of the seed-organ, or *pistil*. The number of stamens in each flower varies from one to twenty, or more. In length they are equal or unequal. In the *Cruciferæ* there are four long and two short, and in the *foxglove tribe* there are generally two long and two short. In position, they may be opposed to the divisions of the petals, or they may alternate with them, which is their normal condition. Sometimes they protrude beyond the corolla, at other times they are wholly included within it. The filament which supports the anther is most commonly straight and filiform. On the summit is that essential part the *anther* (from *antheros*, belonging to a flower), which is generally formed of two small membranous sacs, or lobes, attached immediately to each other, or united by an intermediate connecting body. In form, anthers are subject to great variety, and, like the filaments, they sometimes cohere so as to form a sort of tube, as in the *Compositæ*.

The *pollen* (fine flour) contained in the anthers consists of numerous small bodies, which possess in different plants a very different figure, size, and colour. The number of these in an anther-lobe sometimes amounts to many thousands. In some flowers, the pollen-grains are transparent; in others, they are of a white, purple, blue, or brown, and more frequently of a yellow colour; and they often display exquisite markings on their surface, which enable the pollen of certain orders to be identified under the microscope. When a grain of pollen is dropped into water, it swells, and sometimes bursts, emitting a minute quantity of granular matter, called *fovilla*, which is the portion more essential to fecundation. In orchids and some other plants, the pollen occurs in masses, or *Pollinia*.

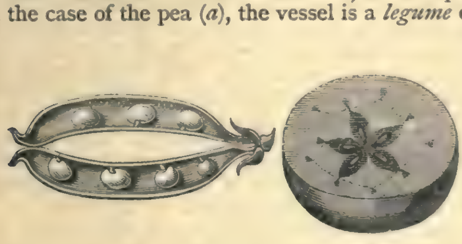
Pistil (from *pistillum*, a pestle).—The pistil is the more or less filamentary body which in most plants rises from the centre of the flower terminating the axis of growth, and is surrounded by the stamens. The pistil represents the female part of fructification. Its parts are—1. The *ovary*, containing ovules or rudimentary seeds; 2. The *style*, or filamentous part; and 3. The *stigma*, or enlarged club-shaped or cloven part forming the apex. The first and last of these are essential, and always present; but the intermediate one, the style, is sometimes not developed, as in the poppy and mangosteen. The pistil consists organically of one or more carpels (folded leaves), which may either be syncarpous (united into one) or apocarpous (separate); in the latter case, we have two or more pistils in the flower.

Having thus briefly described the visible reproductive organs, let us now turn to their functional phenomena. When the flower expands, and its essential organs have arrived at maturity, the anther-valves open and emit the pollen-grains; some of these fall upon the stigma, or terminal point of the pistil, where a peculiar tissue, formed of papillary or hair-like cells, is ready to retain them. A curious phenomenon is now observed. The pollen-grain—a single free cell—develops one or more tubes from its surface, these being formed by its inner membrane, which thus grows through the outer one. These tubes are destined to reach the ovules at the base of the pistil, and thus to carry down from the pollen-grain the matter or influence necessary for fertilisation. The tube, accordingly, penetrates the soft tissue of the stigma, and passes down the centre of the pistil, where a loose conducting tissue is specially formed to facilitate its progress. In this way the pollen-tube often acquires a length several thousand times greater than that of the pollen-cell whence it was produced, its nourishment being derived from the surrounding tissues which envelop it. Mohl regards the development of this filament or

tube as indicating a new analogy between the pollen-grain and the spore of cryptogamic plants; for it is, in fact, a process of germination. The length of time required for the growth of the pollen-tube down to the ovule, is very various in different plants, and by no means depends upon the length of the style; thus, in the night-flowering cactus, which has a style from eight to nine inches long, the pollen-tube reaches the ovules a few hours after the pollen has been applied to the stigma; while in the pine, where there is no proper style, a whole year elapses before the pollen-tubes reach their destination. The lower extremity of the pollen-tube ultimately comes into contact with the ovule, and enters the foramen or micropyle of the latter, so as to reach the embryo sac pre-existing there. The result of the access of the pollen-tube to the ovule, is the production of an embryo in the latter, and the ovule, with its contained embryo, ultimately ripens into a perfect seed. Fertilisation with pollen is essential for the production of fertile seeds, although the ovule exists previous to the act. Fruits may, in some instances, swell and ripen without any process of fertilisation; but in that case, they will not contain seeds capable of producing new plants.

It is not essential for success in this process that the pollen should fall immediately from the anthers upon the stigma, for we have several historical facts which indicate that pollen may retain its vitality unimpaired, in the manner of seeds. Thus, in the cultivation of the date-tree, it is necessary to bring the fruitful plants under the influence of the male flowers; but on one occasion, during a civil war in Persia, the male date-trees of a whole province were cut down by the invading troops, that the fructification of the fertile trees might be prevented, and the season's crop thus destroyed. But the inhabitants, apprehending such a result, had been careful previously to gather the pollen, which they preserved in closed vessels, and thus were enabled to impregnate their trees when the country was freed from the destroying enemy. The pollen-grains of the date and of the European palm (*Chamærops humilis*) are said to have retained vitality after the lapse of eighteen years.

Seed-vessels are various in form—as, for example, in the case of the pea (*a*), the vessel is a *legume* or



a *b*

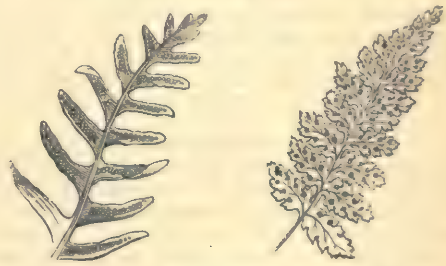
pod; in the apple (*b*), it is a *pome;* and in the filbert, a nut.

All our esculent fruits are in reality so many vessels or receptacles for the seeds; and the various forms in which they appear are individually suitable to the purposes of their growth. As we have already indicated, the seed contains the *embryo*, or germ, of the future plant, which is generally surrounded by a nutritious substance termed the albumen, destined for the support of the young plant before its organs are sufficiently matured to allow of its supporting itself. This albumen varies very much in quantity, sometimes being much smaller than the embryo; while in other cases, as in the coco-nut, it weighs as many or more ounces than the embryo does grains. Its texture is variable. It is generally fleshy, as in the pea and bean; but sometimes it is farinaceous or floury, as in the wheat; at other times it is oily, as in linseed; horny, as in the coffee; or even stony, as in the vegetable ivory palm. If the embryo consists of one seed-lobe or cotyledon, as the wheat, it is said to be *monocotyledonous;* if of two, as in the beech and oak, *dicotyledonous*—and these terms are generally used respectively for endogenous and exogenous; while cryptogamous, or flowerless plants, from being propagated by spores instead of seeds, are said to be *acotyledonous*—that is, without any cotyledon whatever.

FRUCTIFICATION OF FLOWERLESS PLANTS.

As already stated, the lowest forms in which plants make their appearance are those of the *cryptogamous*, or flowerless orders—such as the ferns, lichens, mosses, sea-weeds, and fungi. In these, the mode of fructification is very remarkable, and quite different from that of flowering-plants. They have neither flowers nor proper seeds, but are propagated by minute unicellular bodies called *spores*.

Ferns.—In the ferns (*Filices*), which are the largest and most highly organised of the flowerless orders, little brown patches, called *sori*, may be seen on the under sides of the leaves or fronds (see figs.). Each of these is composed of a number



Ferns, shewing the Sori on the back of the Fronds.

of minute membranous capsules (*thecæ*), which contain the reproductive spores, and which are often furnished with an elastic ring, for assisting in rupturing the spore-case, and thus facilitating the dispersion of the spores. These spores are not the result of a process of fecundation similar to what has been described in the case of flowering-plants. Impregnation takes place, not upon the mature frond, but upon the infant fern, while as yet scarcely visible to the naked eye. The spores, when scattered over the soil, give rise to minute cellular expansions of tissue resembling liverworts, upon which male and female bodies, called respectively *antheridia* and *archegonia*, are produced. The former emit *spermatozoids*, which move about freely, by means of attached cilia. The archegonia have a central canal, leading down to a large globular cell. A spermatozoid enters the archegonial canal, reaches the globular cell, and

fertilises it. This cell divides, and is soon developed into an embryo, with a bud above and a radicle below; and then the circinate fronds shewing the genuine fern-structure arise. As an order, ferns are very widely distributed, generally consisting of a number of leaf-like members called *fronds*, which are the only visible portion of the plant. In some species, however, the stem rises above ground to the height of thirty to sixty feet, forming the well-known *tree-ferns* of New Zealand and tropical islands.

Fern Allies.—In the horse-tails (*Equisetaceæ*) of our marshes and ditches, the spores are placed on bracteated spikes, terminating the stems. Each spore is furnished with two elastic filaments, which are coiled around it, and are very hygrometric. The horse-tails are herbaceous perennial plants, having hollow striated stems, these being either simple or branched. In point of size, they are now insignificant members of the vegetable kingdom; but geology has revealed the gigantic proportions they bore in ages long past, when, instead of slender stems of a foot or two high, they reared their gigantic pillar-like trunks to a height of twenty or thirty feet. The spores of the pillworts (*Marsileaceæ*) are inclosed in little ball-like receptacles at the bases of the leaves (see fig.); the club-mosses (*Lycopodiaceæ*) have little cone-like spikes at the tips of their branches, between the scales of which occur small spores, while large ones occupy the axils of the leaves lower down.

Pillwort.

In the true mosses (*Musci*), the spores are inclosed in urn-shaped capsules, which generally stand out from the leaves on slender hair-like stalks. In the liverworts and lichens there is a somewhat similar provision; and in the algæ (sea-weeds), the spores are often inclosed in the substance of the plant.

The *fungi*, or mushroom tribe, are extremely diversified in their size, shape, colour, and consistence. They are entirely composed of cellular tissue. The common field-mushroom is one of the best known, and may be cited as typical of the family; but the mould on cheese, stale bread, the mildew on vines, the rust and smut on corn, and many other minute and yet unobserved appearances of a similar nature, are all fungi. Their organs of reproduction consist of spores variously arranged in different tribes, presenting resemblances in some to the lichens, and in others to algæ.

There is still much to learn respecting the cryptogamic orders, which yearly receive increasing accessions of students, for it is in these plants that the whole vital phenomena of vegetation can best be studied. 'We are entirely ignorant,' says Professor Lindley, 'of the manner in which the stems of those that are arborescent are developed, and of the course taken by their ascending and descending sap—if indeed in them there really exist currents similar to those of flowering-plants; which may be doubted. We know not in what way the fertilising principle is communicated to the sporules or reproductive grains; the use of the different kinds of reproductive matter found in most tribes is entirely concealed from us. It is even suspected that some of the simplest forms—of algæ and fungi, at least—are the creatures of spontaneous growth: and, in fine, we seem to have discovered little that is positive about the vital functions of those plants, except that they are reproduced by their sporules, which differ from seeds, in germinating from any part of their surface, instead of from two invariable points.'

General Economy of Flowerless Plants.—Insignificant and lowly as the cryptogamia may appear to the eye of the common observer, they are nevertheless important auxiliaries in the operations of nature. It is true that man and his works may suffer from their ravages, that mildew, rust in corn, and other microscopic forms of vegetation, by their rapid increase and destructive effects on the substances from which they spring, may cause incalculable damage; but this very scourge provides an incentive to intelligent prevention and care, while in creation there are no more useful scavengers of decaying matter than the fungi. In a dry season, for example, and on a favourable soil, rust rarely makes its appearance: certain conditions are necessary for its development; and it is to obviating these that the farmer must look for exemption from this destructive malady in his crops.

It will now be understood that mould is a fungus, produced by a previous deposit of germs in the tissue or on the surface of the object on which it grows. The proximate cause of its development is generally damp, and without this condition, the embryo remains in a dormant state. Still it may be asked, how cheese happens to have green mould at its very centre?—the reply is, that the germs floating in the atmosphere had various opportunities of finding admission into this article of diet. They may have been deposited on the grass of a field; the grass was eaten by the cow, and the germs were so lodged in the milk; or, what is more probable, the germs fell upon the curd, and there lay concealed till a certain dampness in the cheese brought their vegetative powers into operation. It is well known that the exposure of curd for a day to the atmosphere will have the effect of producing cheese liable to mould. A fully more surprising instance of fungus vegetation in a secluded situation, is that which occurs in the fermenting of yeast and other substances. Fermentation is, in one respect, a chemical process, forming a first step towards dissolution; but the action is also vegetative. The whole mass of matter gradually assumes the condition of active vegetative growth. The fungus germs which had been incorporated in the material begin to live and expand, each being a plant which grows and gives rise to new plants of the same species, until the entire fermenting principle is exhausted.

One great object which nature has in view by the germination and dispersion of the algæ, mosses, and lichens, is clearly that of preparing the way for a higher order of vegetation. It cannot possibly escape our observation that the tendency to vegetate is a power restless and perpetual. We hew a stone from the quarry, and place it in a damp situation, on the ground or in a wall, and shortly a green hue begins to creep over it. This is the commencement of a vegetable growth, produced by germs floated in the atmosphere; which, being attached at random to the stone, have been

brought to life through the agency of the moisture. Other stones equally exposed, but in dry situations, have also received a clothing of these germs, but circumstances not being suitable, they have not been developed: give the moisture, and they will immediately appear. We hew another stone from the quarry, and build it into the pier of a bridge, just within the surface of the water: shortly, a kind of green alga will appear; but the wet being in greater abundance, and more continuous, the growth will become more luxuriant than that of the terrestrial wall. Instead of the simple green coating, we have the addition of long filaments resembling hairs (*Confervæ*), which float and accommodate themselves to the water around.

Nature is incessantly working out vast ends by humble and scarcely recognisable means. It seems to be a principle that nothing shall remain stationary or unchanged. The whole surface of our planet is every instant altering in its features: mountains are being washed down into the plains, rocks are mouldering into soil, the sea is filling up at one place and encroaching on the land at another, and water-courses are constantly shifting their outlines. The duty of filling up seas, ponds, lakes, and rivers, is consigned to diverse means within the animal and vegetable economy; and one of these is the growth of algæ and other aquatic plants. Take a pond of water, and shut off its means of supply from rivulets and springs, and then observe what an effort nature will make to fill it up. The sides and bottom become speedily covered with a luxuriant crop of confervæ; other plants, which grow only in water, begin to make their appearance, their seeds being wafted thither by winds; at length the superficial matting of herbage is able to support the weight of birds; there is alternate vegetation and decay; finally, the pond is filled up, and a forest of the highest order of trees may in time cover the site of the original humble confervæ. What, indeed, are the extensive peat-mosses but lakes and pools choked with vegetable matter, which remains in a half-reduced condition. Thus we see that the green alga which grows upon stones in the water, humble and apparently insignificant as it is, performs a distinct and important part in creation.

SPECIAL PHENOMENA OF VEGETATION.

In addition to the ordinary functions of the organs, which are common to all plants, there are certain anomalous phenomena which cannot be reduced to regular laws, and which merit notice in this place; the most remarkable of these are the occasional *irritability* and *movements* of plants.

Irritability.—The irritability of animals depends entirely on their nervous system; but as plants have no nervous system, their irritability is more difficult to be accounted for. The principal phenomena of vegetable irritability may be divided into three kinds—namely, those caused by atmospheric influence, those depending upon the touch of other bodies, and those which appear to be perfectly spontaneous. Atmospheric influence occasions the closing of the leaves over the extreme point of the young shoot at night, as may be observed in the chickweed and several other common plants. The folding of some flowers in the absence of the sun, and the opening of others as soon as that luminary has withdrawn its beams, are ascribable to a similar cause. The pimpernel closes its flowers on the approach of rain. Most blossoms expand during sunshine; but the evening primrose, on the contrary, will not open its large yellow flowers till the sun has sunk below the horizon; and the night-flowering cereus only expands its magnificent blossoms about midnight. Some flowers are so regular in their hours of opening and shutting, that Linnæus formed what he called *Flora's Time-piece*, in which each hour was represented by the flower which opened or closed at that particular time. Solar light is the principal agent in producing these phenomena; but in some cases flowers will open by artificial light. De Candolle found blossoms expand beneath a lamp nearly as well as beneath the sun itself; and the crocus and gentian, which close at night, will expand as wide as possible when gently exposed to the light and heat of a fire. One of the most remarkable circumstances respecting the effect of atmospheric influences is, that the same causes do not affect all plants, and yet no peculiarity of construction has been discovered in those that are so affected to distinguish them from those that are not.

The irritability produced by external touch is a familiar but little understood phenomenon. The movements of the sensitive plant are well known; and it is also known that if the ripe seed-vessels of the noli-me-tangere be touched in the slightest manner, they will open with elasticity, and scatter their contents. In the same manner the fruit of the squirting cucumber (*Elaterium*) throws out its seeds, and the pulp in which they are contained, with violence, and to a considerable distance. The stamens of the barberry, when touched with a pin, spring forward towards the stigma, after which they return to their original position; while the column of the stylidium, which includes the style and stamens, and which generally hangs on one side, when touched, springs with a jerk to the other side of the flower. The most remarkable instance of irritability by contact is that exhibited by Venus's fly-trap (*Dionæa muscipula*), a native of North America. The leaves are very curiously constructed. They have broad leaf-like petioles, at whose extremity are two rounded fleshy lobes, which form the real leaf, and which are armed with strong spiny hairs, three on the blade of each lobe, and a fringe of longer ones round the margin. When an insect touches the central hairs, the leaf collapses, and the insect is entrapped. The leaf generally remains closed till the insect is dead. In Sarracenia, or the side-saddle flower, the leaves have a pitcher-shaped petiole, which forms a trap for flies and other insects, as well as the leaves of the Nepenthes, or pitcher-plant, but these do not display irritable phenomena.

a, Leaf of Venus's Fly-trap.
b, Leaf of Sarracenia.

The *spontaneous movements* of plants are equally difficult to be accounted for with those occasioned by atmospheric phenomena or by external touch.

It is true that the leaves elongate, the flowers expand, the anthers burst, and the seed-vessels open spontaneously; but these are movements caused by the progressive development of the plant, and subjected to regular laws. The spontaneous movements to which reference is now made are quite different—as, for example, those of the leaves of *Hedysarum gyrans*. This plant has compound leaves, the terminal leaflet of which displays a slight oscillatory motion; but the side-leaflets have such eccentric movements, as to render it difficult, if not impossible to explain them, and which might appear, indeed, to a fanciful mind as though the whole plant were actuated by a feeling of caprice. Generally, all the leaflets twist and whirl themselves about in an extraordinary manner, though the air of the hot-house in which they grow is perfectly still; but frequently the leaflets on only one side will be affected, and sometimes only a single leaflet will move, or all will become motionless together; and when this is the case, it is quite in vain to attempt to set them again in motion by touching them; though sometimes in a moment, after the touching has ceased, the leaflets will begin to move again as rapidly as before. In like manner, the side-leaflets frequently continue their movements all night, while the terminal leaflet remains quietly folded up. Cold stops the motion of the leaves, which begins again so soon as the heat of the stove in which the plant grows is renewed.

Plants may be deprived of their irritability by the vapour of prussic acid, chloroform, or ether.

Colour.—The colours of plants present many points of interest for the consideration of the student, and are connected with many important phenomena in vegetation. It is to colour, perhaps, more than to form, that vegetation, as a whole, often owes its importance in the landscape. The gay colours of plants usually reside in the corolla, the leaves being usually some shade of green; but in the case of sea-weeds and other cryptogams, the whole plant is often of a bright red, or green, or olive, according to the species, a character which has afforded the basis of the classification of sea-weeds now in use.

The green colour of leaves and the gay colour of flowers depend upon different kinds of colouring-matter contained in the cells of the plant, for the cell-walls are without colour themselves. In the green parts of plants, this colouring-matter is in the form of microscopically minute green granules of chlorophyll, which are only produced under the action of light; hence plants grown in the dark are etiolated. The changes which it undergoes, according to its state of oxidation, explain the tints which green leaves acquire in autumn. The yellow leaves of autumn contain proportionately more wax than the green leaves of summer, and the yellow rind of ripe fruits more than the green rind of unripe fruits.

The colours of parts not green are due to a different kind of colouring-matter, termed chromule, whose chemical relations to chlorophyll have not been fully investigated. Chromule is usually diffused throughout the sap of the cells; as in the flower of the tulip, for example, a strip of the epidermal tissue of which will shew well, under a common compound microscope, the beautiful arrangement of cells of different colours, so as to give the general effect seen in this gaudily painted flower. In some cases, however, chromule is found in the form of distinct granules. The colours of flowers are arranged in two series—the cyanic or blue, and the xanthic or yellow. A species belonging to the blue series may exhibit all shades of white, purple, and violet, but will not become yellow; and one belonging to the yellow series may exhibit all shades of white and orange, but will not become pure blue. Both series unite in red. Although light is essential to the development of the green colour of leaves, its immediate action is not always required for the development of the chromule of flowers—a fact quite in accordance with the practice of florists, who keep their favourite dahlia and pansy blooms covered up in their later stages. In accordance with this, also, is the fact, that flowers grown in the shade are seldom different in colour from those fully exposed to the air and light. Flowers may be made to change their colours by the influence of the soil in a most remarkable manner. The petals of the common hydrangea, which are naturally pink, are said to be made blue by planting the shrub in soil impregnated with iron, or providing it with charcoal. The change produced in tulips, carnations, heart's-eases, &c. is still more extraordinary. The flower of a seedling tulip is generally uniform; and after remaining of this colour two or three seasons, it will suddenly *break,* as the florists term it, into the most brilliant and varied tints of rose, white, yellow, brown, or purple, without leaving any trace of the original colour. To produce this change, florists try a variety of means, all of which have relation to the soil; for example, they sometimes keep their tulips in poor soil, and then suddenly transplant them into one exceedingly rich; or they reverse the process: at other times they change them suddenly from a sandy to a clayey soil. Even the chlorophyll of plants is often developed under circumstances where the influence of light is very slight, and would appear to depend in some measure upon other agents. Ferns and mosses have been found green in mines where they have grown in almost total darkness; and green and red sea-weeds of the most brilliant tints grow at great depths in the ocean, where the light, being weakened by passing through such an immense body of water, can have but little colouring effect.

Although it has been stated by Ruskin that 'the natural colour of objects never follows form, but is arranged on a different system,' the investigations of Professor Dickie on the relations between colour and form in plants seem to indicate a different result. He finds—1. That in polypetalous and gamopetalous flowers, of regular form—such as the primrose, gentian, and pimpernel—the distribution of colour is uniform on the different petals, whether free or in cohesion, whatever be the number of colours present; 2. That flowers whose form is irregular—as, for example, papilionaceous flowers, where certain petals are larger than the others—present an equally irregular distribution of colour, whether one or more colours be present; 3. That different forms of corolla, in the same head of flowers, often present differences of colour; but all of the same form agree also in colour.

Fragrance.—The cause of fragrance in flowers has never yet been fully explained. All organised bodies consist partly of volatile matters,

and thus we can readily account for the odours given out by decaying animal and vegetable substances, as they evidently proceed from the volatile parts being liberated by decomposition. The fragrance of flowers, however, escapes while the plants are in a living state, and that most abundantly when they are in vigorous and healthy condition. Besides the flowers, other parts of living plants frequently exhale fragrant odours—such as the leaves of the myrtle and geranium, and the wood and bark of pines. All these odours proceed from oily or resinous matters contained in the receptacles of secretion; but the laws which regulate their liberation, and define their physiological uses, are as yet imperfectly known. The odours of plants are of three kinds: permanent, fugitive, and intermittent. Permanent odours are those given out slowly by the plant, not only whilst it is living, but also after the fragrant part has been separated from the living plant. Of this kind are the odours of fragrant wood, of the dried petals of roses, and some other flowers. Intermittent odours are the most difficult to be accounted for by the vegetable physiologist. It is well known that the night-smelling stock and several other plants, which are entirely devoid of scent during the day, are delightfully fragrant during the night. One of the orchideous plants produces its powerful aromatic scent only when exposed to the direct rays of the sun; and the flower of the night-blowing cereus is fragrant only at intervals during the time of its expansion.

Tastes.—The tastes produced by vegetable substances are generally recognised as sweet, acid, bitter, astringent, austere, or acrid. As a general law, it may be stated that the drier and warmer the situation, the more exposed to light, and the slower the growth of any vegetable, the more intense is its peculiar flavour.

Luminosity, Heat, Electricity.—The luminosity of plants—that is, the evolution of light either from living or dead vegetable structure—is a rare and curious phenomenon. Flowers of an orange colour, as the marigold and nasturtium, have been occasionally observed to present a luminous appearance on still warm evenings; this light being either in the form of slight electric-like sparks, or steadier, like the phosphorescence of the glow-worm. Certain fungi, which grow in warm and moist situations, produce a similar phosphorescence; and decaying vegetables, like dead animal matter, have been observed to emit the same kind of luminosity. This phenomenon seems connected with the absorption of oxygen; and the parts emitting it are said to be most luminous when immersed in pure oxygen, and cease to emit it when excluded from that element.

The evolution of heat by living plants is a more common phenomenon. We are aware that warm-blooded animals have the power of keeping up a certain temperature within them, which varies at certain stages of their growth, and perhaps periodically. This result is obtained by respiration—the oxygen of the atmosphere uniting with the carbon of their blood, and producing a kind of combustion. A similar, though less understood phenomenon, seems to take place in the respiration of plants. In germination, heat is sensibly evolved; a piece of ice placed on a growing leaf-bud will dissolve, when it would remain unchanged in the open air; and experiment has proved that the surface of plants is three or four degrees higher than the surrounding medium. Again, the internal temperature of a large trunk is always higher than the surrounding atmosphere, and though young shoots are sometimes frozen through, the general structure both of the wood and bark is such as to conduct heat so slowly, that the internal warmth is seldom reduced beyond what seems necessary to the maintenance of vitality. Generally speaking, it may be asserted that plants possess an internal vital temperature, and that in the so-called process of respiration—the giving off of carbonic acid or oxygen, as the case may be—a certain degree of heat is evolved; but precise experimental results are wanting. At the time that the essential organs of flowers are fully developed, a certain amount of heat is given out. This heat is rapidly carried off by the air, and is therefore not easily detected; but in certain cases, especially in plants belonging to the natural order *Araceæ*, the elevation of temperature is very marked; the temperature inside the flowering spathe varying from 10° to 50° F. above the surrounding atmosphere.

The connection of electricity with vegetable growth has recently excited the attention of physiologists; but little positive information has yet been ascertained. It has been long known that growth takes place with great rapidity during thundery weather; but this may result from the nitrogenised products of the showers which then fall, as well as from the effects of electricity. The progressive states of vegetable growth are the result of chemical changes; and as these changes are more or less accompanied by electricity, it is supposed that plants evolve electricity as well as heat. The general electric state of plants is said to be *negative;* and some have attempted to connect the luxuriant vegetation of the tropics with the thunder-storms of these regions, on the supposition that when the atmosphere is *positively* electrified, the two opposite states will give rise to such commotions.

SECRETIONS AND EXCRETIONS OF PLANTS.

Substances of varied properties are secreted by plants, and otherwise formed in their tissues according to their respective natures, and their healthy or diseased condition at the time of secretion. Some of these substances are produced by the ascending sap; but the greater number are deposited by the elaborated or proper juice, and consequently are seldom secreted during spring or early summer. The intensity of those derived from the latter source depends in a great measure upon the influence of solar light; hence they are much stronger, and more abundantly produced, in tropical than in temperate climates. From the manner in which many of these are deposited or ejected, they appear to be of little or no utility in the vegetable economy. Some of them may be regarded as *excretions* as well as *secretions;* but whether they are to be considered as essential components of the sap, or evacuations necessary to the healthy condition of the organs, has not yet been determined. Being exceedingly varied in their properties, they are of great utility to man as articles of food, medicine, ornament, and luxury.

The economical applications of vegetable secretions and excretions are so numerous, that it would be impossible, in our limited space, to enter upon

anything like details. It is even difficult to attempt any classification of them; for, though differing in their properties and external appearance, many of them are identical in chemical composition, and, subjected to peculiar treatment, readily pass into new and singular combinations. Some, for instance, are saccharine, as the juice of the sugar-cane. Many are oleaginous, balsamic, or resinous; some are narcotic, aromatic, or mucilaginous; while others are astringent, purgative, or poisonous. For examples of these divisions, we have such substances as palm and olive oil, myrrh, resin, opium, camphor, gum-arabic, tannin, gamboge, prussic acid, aloes, colocynth, and many others of everyday familiarity.

Besides the proper excretions and secretions, there are several adventitious substances found in plants, which are not the products of vital organisation. Lime, for instance, is found in the ashes of many plants in union with acids; sometimes it is excreted in the form of a thin crust on their leaves, and in other cases in peculiar cells. Silica also occurs in considerable quantities, especially in the stems of reeds and grasses; it forms the glossy pellicle of the cane, and is sometimes found in the joints of the bamboo, where it is deposited in a soft pasty mass, called *tabasheer*, which ultimately hardens into pure semi-transparent silica. *Equisetum hyemale*, called Dutch-rushes, contains a large quantity of silica, and is used for polishing mahogany. Besides these earths, there are various metallic oxides and salts, and the well-known alkalies—potash and soda. The physiological uses of such products are but imperfectly known. Many of them—such as starch, gum, sugar, and the fixed oils—directly administer to the support of the young plant and to the formation of new tissues. Others, again—such as silica and metallic oxides—give hardness and stability to the stems and branches; some give elasticity and pliancy to the young shoots, thereby preventing them from being broken by winds; and several—as tannin, for example—seem to administer to the durability of the woody tissue.

METAMORPHOSES OF PLANTS.

The metamorphoses of plants, in the general sense of the term, form one of the most interesting sections of Vegetable Physiology. Technically, it is termed *Morphology*—that is, a consideration of the changes and transformations which various parts of plants undergo, either from natural or artificial causes. We know, for instance, that many plants are made to change their appearance and qualities by cultivation; that by grafting, hybridising, and other means, the gardener can change the size, colour, and qualities of his fruits and flowers: and that analogous changes take place in a state of nature—such as the conversion of petals into leaves, and leaves and branches into thorns and spines. It is also well known that flowers become double by changing their stamens into petals; and it is from a knowledge of such facts that botanists have asserted that all the parts of the flower and fruit, as well as the appendages of the stem or ascending axis, are modifications of a single typical organ, and may be considered *as leaves adapted to special purposes.*

The law which it seeks to establish may be stated to be this: that all the appendages of a plant have a common origin with the leaf, and may therefore successively assume the form and appearance of that primary organ. The branches of the stem take their origin from leaf-buds, and are clothed with branches and leaves by the same process as in the main stem. Towards the point of fructification, the leaves assume the form of bracts; these, again, are succeeded by the leaf-like sepals of the calyx; and next by the petals of the corolla. Within the petals are the stamens—which sometimes assume a leafy form—next the pistil, and ultimately the seed-vessels. Even the seeds are but leaves in another form. Thus, the growth and reproduction of plants may be regarded as a circle of leaf-like changes, the leaf, or some modification of it, being in all cases the organ which administers to the functions of vitality. As there is an indubitable passage from leaves to every other organ, so may any one organ be found to revert to the primary form of the leaf. In the double-flowering cherry, so common in shrubberies, the stamens are changed into petals, and the ovary into a green leaf!

The *hybridism* of plants is closely allied to the subject of morphology, and is, in fact, a process of transformation of an artificial character. As among animals two distinct species of the same genus will produce an intermediate offspring—such as the *mule*, which is the offspring of the horse and ass—so among vegetables, two species belonging to the same genus can be made to produce a *hybrid;* that is, a new plant possessed of characters intermediate between its parents. This power of hybridising is more prevalent among vegetables than animals; for the different species of *many* genera of plants are capable of producing this effect, if the pollen of one species be put upon the stigma of another. And this crossing may even be applied to separate genera. Hybrids have not the power of perpetuating their kind like naturally distinct species; for, though occasionally fertile in the second and third generations, they have never been known to continue so permanently. But though incapable of propagating beyond a limited period, the pollen of the parent species may be made to fertilise them, or their pollen to fertilise the parent; but in either case the new offspring gradually merges into the original species. Thus nature has wisely set a limit to the intermingling of species, by which they are preserved from ultimately running into confusion and disorder. In an economical point of view, hybridism is of great value to man. By a knowledge of its principles, he has been enabled to modify the characters of natural species, so as to adapt them to his special purposes; and thus have arisen most of those beautiful varieties of what are termed florists' flowers, which now adorn the flower-garden. So also by crossing varieties of the same species, our grains, fruits, and kitchen vegetables have been brought to a high state of perfection.

SYSTEMATIC BOTANY.

BOTANY is the science whose purpose it is to investigate the Vegetable Kingdom. *Vegetable Physiology*—treated of in the preceding article—is that department of the subject which explains the organisation and vital functions of plants; *Systematic Botany*, that which recognises their arrangement into groups, according to their form and structure. The former relates to functions which are common to all vegetables; the latter takes notice only of such peculiarities as serve to distinguish one species from another, or one family from another family. The vegetable kingdom is supposed to contain upwards of 150,000 species; and therefore, without some system of arrangement into smaller groups and orders, it would be difficult to acquire a knowledge of the special characteristics of plants, or to convey that knowledge to others by any process of description. It is the aim of Systematic Botany to obviate this difficulty, by classifying plants according to certain types and resemblances which are common to a number of species; thus making one description equally applicable to a class as to a species.

The advantages of classification in lessening the labour of memory and description, become strikingly apparent when we reflect on the difficulty which would exist were each plant to be known by an entirely distinct name. For example, there are many species of roses, all of which are known by the generic term *Rosa*, each having a second or specific name to designate it separately, as *Rosa canina* (the dog-rose), &c. Now, if a botanist hear of a plant called *Rosa*, though its specific name be quite new to him, he has instantly a general idea of what sort of plant it is, from his previous knowledge of the common characteristics which belong to the genus *Rosa*. The principle of classification is to assemble those plants which bear most resemblance to each other; and this has been done in different ways by different botanists; each method being called the *system* of the individual who devised it—as Tournefort's system, Linnæus's system, Jussieu's system. Of the several systems which have been suggested, only two are in use at the present time—namely, that of Linnæus, the great Swedish naturalist (1707-1778); and the Natural System, in its numerous modifications, that of Jussieu, an eminent French botanist, who, during the long period between 1789 and 1836, was closely engaged in improving the nomenclature and arrangement of the vegetable kingdom, having afforded the basis of those mostly in use.

The system of Linnæus is founded on the *sexes* in plants—the number, situation, proportion, and connection of stamens and pistils, which are regarded as respectively the male and female organs, being chosen to supply characters for the classes and orders. This system appears at first sight extremely simple, as it depends entirely on the counting of so many visible parts; but it is very uncertain, as the number of stamens often differs, from accidental circumstances, in plants of the same genus; and it tells nothing of the plant but its class and order, which lead only to the discovery of its technical name, as plants of the most opposite qualities frequently agree in the number and disposal of their sexual organs. This mode of classification is known among botanists as the Sexual System, or the *Artificial System*, because it is founded on mere artificial enumeration, on a single series of characters, and not upon natural qualities or resemblances of the plants so arranged. That of Jussieu, on the contrary, is founded on the natural affinities; and the botanist who is acquainted with its principles can at first sight assign any plant to its proper class and order, as there is always a general resemblance among the plants belonging to the same natural order. Again, knowing the order, which is usually typified by some common plant, he can predict as to its properties—a species of information which the artificial system does not attempt to convey. Jussieu's method has been greatly improved since the time it was suggested, particularly by the late Professor De Candolle of Geneva; and it is his modification of the original plan, with further improvements, which constitutes the most generally adopted *Natural System* of the present day.

According to both systems, plants are divided into classes, orders, genera, species, and varieties. A *class* consists of plants resembling each other in some grand leading feature, and as strongly differing from another class as mammalia do from birds, for example. Thus, flowering-plants with one cotyledon (or seed-lobe), whose trunks increase in thickness from within—as the palm—form a distinct class; while flowering-plants with two cotyledons, and whose trunks increase by external layers, constitute another class. An *order* consists of plants still more closely allied, so that many orders may be found in the same class. Thus, as ruminant or cud-chewing animals form an order of mammalia, so do the leguminous or pod-bearing plants constitute an order of dicotyledonous vegetation. A *genus* consists of plants so very closely allied, that they may be compared to members of the same family. The pea, for example, constitutes a genus of leguminous plants, just as sheep form a family of the ruminants. A *species* may be compared to one of the members which compose the family; thus the garden-pea and sweet-pea are different species of the same genus. A *variety* is merely a departure from the common appearance of the species in trivial characters, or differences which arise from climate, situation, greater or less humidity of soil, and other accidental causes. The boundaries between species and varieties are often very vague, some botanists regarding those plants as species which others consider mere varieties; but much doubt might be removed by attending to the fact, that a species reproduces itself from seed, and is always persistent under the same circumstances, whereas a variety has often a tendency to revert to its parent species, unless propagated by cuttings, and fostered by artificial means. A *hybrid* is a plant raised by fecundating the stigma of one species with the pollen of another—a process which

occasionally occurs among plants in a wild state, but is more common in cultivation. Unless perpetuated by artificial processes, they are liable to die out, or revert to their original stock.

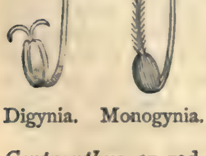
In botanical nomenclature, the name of every plant consists of two words; the first is the name of the genus, and the second that of the species—as, for example, *Quercus alba*, the white oak. When three names are given, the third signifies that the plant is a variety; and this is sometimes more strongly marked by using the contraction *var.* before the third name—as, *Quercus Ilex* var. *crispa*, the curled-leaved variety of the evergreen oak. The third name is for the most part omitted in botanical catalogues, and the varieties indicated by letters of the Greek alphabet—observing that the varieties begin with the letter β—as, *Quercus Ilex β crispa*.

The primary arrangement of plants, according to both the artificial and natural systems, is into those with flowers and those without flowers. The first division, or that which includes the flowering-plants, is distinguished by the name PHANEROGAMIA, and in them the organs of reproduction are apparent. It comprehends all the trees and shrubs used in the economical arts, as well as the common ornamental plants of our gardens, and, in short, all those that have distinct organs—as leaves, branches, flowers, and proper seeds. The second division, known by the term CRYPTOGAMIA, embraces, as the name implies, those plants in which the organs of reproduction are not apparent—as the ferns, lichens, mosses, and sea-weeds. They have no flowers or seeds, in the common acceptation of these words, and their *fronds* or leaves are very different from those of flowering-plants; instead of flowers, fruit, and seed, they are furnished with little cases or *thecæ*, and in these are lodged the reproductive spores, minute as the particles of the finest dust. Here the resemblance between the two systems ceases—their classes and orders being arranged on totally different principles. We shall present, in the first place, an outline of the Linnæan system, both on account of its priority and simplicity, and as an initiatory step to gaining a knowledge of the different forms of flowers. It is true that it is now disused by most men of science; but for the reasons already stated, as well as from the fact that many excellent works have been arranged on its plan, it is necessary that the general reader, as well as the botanist, should have an acquaintance with its leading features.

THE LINNÆAN SYSTEM.

The sexuality of plants had been discovered before the time of Linnæus; but as far as is now known, he was the first who suggested the adoption of this characteristic as a basis of classification. According to his system, the vegetable kingdom is divided into twenty-four *Classes*, founded upon the number, the proportionate lengths, the connection, or the situation of the stamens. These classes are again subdivided each into one or more *Orders*, depending upon the number of the pistils, the presence or apparent absence of a seed-vessel, its shape, or the number and connection of the stamens, or on the arrangement of the florets. Terms compounded of the Greek numerals and the word *andria*, or male, are for the most part used to designate the classes; and similar compounds of these numerals, and the word *gynia*, or female, are employed to designate most of the orders. The following synopsis presents an outline of the system.

CLASSES.			ORDERS.
1. Monandria	1 stamen		has 2—Monogynia and Digynia, or 1 and 2 pistils.
2. Diandria	2 stamens		" 3—Monogynia, Digynia, and Trigynia.
3. Triandria	3 "		" 3—Monogynia, Digynia, and Trigynia.
4. Tetrandria	4 "		" 3—Monogynia, Digynia, and Tetragynia.
5. Pentandria	5 "		" 6—Mono., Di., Tri., Tetra., Pentagynia, and Polygynia.
6. Hexandria	6 "		" 4—Monogynia, Digynia, Trigynia, and Polygynia.
7. Heptandria	7 "		" 4—Monogynia, Digynia, Tetragynia, and Heptagynia.
8. Octandria	8 "		" 4—Monogynia, Digynia, Trigynia, and Tetragynia.
9. Enneandria	9 "		" 3—Monogynia, Trigynia, and Hexagynia.
10. Decandria	10 "		" 5—Monogynia, Digynia, Trigynia, Pentag., and Decagynia.
11. Dodecandria, from 12 to 19	"		" 7—Mono., Di., Tri., Tetra., Penta., Hexa., and Dodecagynia.
12. Icosandria	20 or more "	on the corolla or calyx	" 3—Monogynia, Di.-Pentagynia, and Polygynia.
13. Polyandria	20 or more "	on the receptacle	" 6—Mono., Di., Tri., Tetra., Pentagynia, and Polygynia.
14. Didynamia	4 "	2 long and 2 short	" 2—Gymnospermæ and Angiospermæ.
15. Tetradynamia	6 "	4 long and 2 short	" 2—Siliculosa and Siliquosa.
16. Monadelphia, all the filaments united			" 8—Tri., Pent., Hex., Hept., Oct., Dec., Dodec., and Polyand.
17. Diadelphia, filaments united into two bundles			" 4—Pentandria, Hexandria, Octandria, and Decandria.
18. Polyadelphia, filaments in three or more bundles			" 2—Decandria and Polyandria.
19. Syngenesia, five stamens united by their anthers			" 5—Polyg.-Æqualis, Superfl., Necess., Frustranea, Segregata.
20. Gynandria, the stamens growing on the pistil			" 3—Monandria, Diandria, and Hexandria.
21. Monœcia, flowers with stam., others with pist. on same plant			" 10—Mona., Di., Tri., Tet., Pen., Hex., Oct., Icos., Polyan., Monadelphia.
22. Diœcia, stamens on one plant, and pistils on another			" 13—Mo., Di., Tr., Tet., Pen., Hex., Oc., En., Dec., Do., Ic., Polyand., and Monadelphia.
23. Polygamia, unisex. or bisex. flowers on same or diff. plants			" 2—Monœcia, Diœcia.
24. Cryptogamia—inconspicuous flowers			" 5—Filices, Musci, Lichenes, Fungi, Algæ.

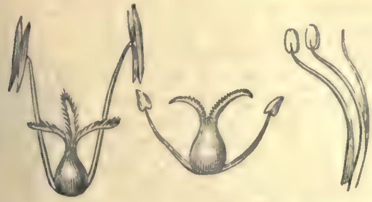


Digynia. Monogynia.

I. MONANDRIA.—The first order of this class contains many highly ornamental exotics, chiefly herbaceous plants, with large leaves and showy flowers. Examples—turmeric, arrow-root, and ginger of commerce. Several of the genera are British—as *Hippuris*, or mare's-tail, and *Centranthus*, or red valerian. The second order, DIGYNIA, contains *Callitriche*, the water-starwort, and *Blitum capitatum*, the strawberry blite.

II. DIANDRIA.—Flowers with two stamens, and with one, two, or three pistils; thus constituting three orders, of which there are upwards of sixty genera. The first, MONOGYNIA, contains by far the greater number of the genera. Examples—the speedwells, olive, fragrant jasmine, lilac, and many evergreen shrubs. The rosemary, and the numerous species of sage and salvia, are ranked

in this order, though some botanists have suggested the removal of the latter plant to the class DIDYNAMIA, because, in addition to the two perfect



Trigynia. Digynia. Monogynia.

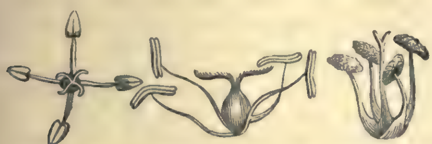
stamens, there are the rudiments of two others in the flower.

III. TRIANDRIA.—Almost all the grasses, including the grain-bearing *cereals*, are found

Trigynia. Digynia. Monogynia.

in this class. The crocus, corn-flag, and iris, and many allied foreign genera, also belong to it.

IV. TETRANDRIA.—Flowers with four stamens *of equal length*. The equal length of the stamen should be specially kept in mind, because the fourteenth class (DIDYNAMIA) has also four stamens, but of these two are longer than the others. Many of the genera of this class are beautiful shrubs and



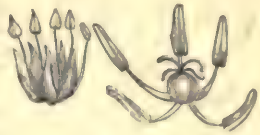
Tetragynia. Digynia. Monogynia.

trees, chiefly natives of the Cape of Good Hope and Australia—as the *Proteas*, *Hakias*, *Banksias*, and the splendid waratah or *Telopia speciosissima*. The common pond-weeds (*Potamogeton*), the bed-straws (*Galium*), and the Lady's-mantle (*Alchemilla*), also belong to this class.

V. PENTANDRIA.—The curious *Stapelia*, bearing flowers of uncommon character both in shape

Digynia. Monogynia.

and colour, and moreover diffusing a scent so loathsome, that blow-flies lay their eggs on the petals! The dodder (*Cuscuta Europæa*), the elm-tree, the ornamental laurustine, the elder, the sumach family, the Grass of Parnassus, pansy, primrose, forget-me-not, hemlock, flax, potato, and other plants, belong to this class.



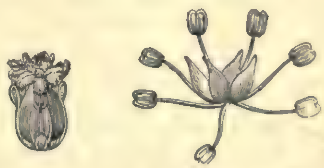
Pentagynia. Tetragynia.

VI. HEXANDRIA.—Flowers with six stamens of *equal length*. By far the greater number of our bulbous flowering and culinary plants—as the narcissus, the tulip, the lilies, the long-lived American aloe, the magnificent *Crinum* and *Pancratium*, the pine-apple, the onion, asparagus, &c.—belong to this class.

Digynia.

VII. HEPTANDRIA.—This class is illustrated by the *Æsculus* and *Pavia*, better known by the name horse-chestnuts. It is remarkable that among above 3000 genera, so few should occur with seven stamens. The chickweed winter-green (*Trientalis Europæa*)

Digynia. Monogynia.



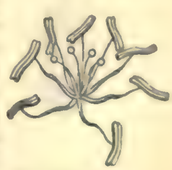
Heptagynia. Tetragynia.

is the only British plant belonging to this class.

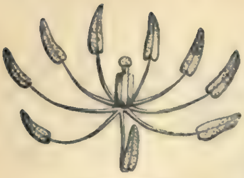
VIII. OCTANDRIA.—The heaths are the most conspicuous and numerous examples of the class. Of this family alone there are about 550 species

Trigynia. Digynia. Monogynia.

already described, chiefly natives of the southern parts of Africa. Six are found in Britain, and several in other parts of Europe. The curious *Rhexia*, the day and night flowering *Œnothera*, the *Fuchsia*, the *Mezereon*, the sea-side grape and soap-berry of the West Indies, the curiously organised *Bryophyllum*, and other genera, belong to the class.

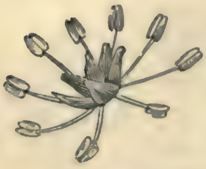


Tetragynia.



Monogynia.

IX. ENNEANDRIA.—This class includes the cinnamon, the laurel, the medical and culinary rhubarb, the flowering rush of Britain (*Butomus umbellatus*), found in ponds and ditches in a few localities in this country.



Hexagynia.

Trigynia.

X. DECANDRIA.—Many of the species of this

Decagynia.

Pentagynia.

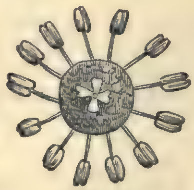
Trigynia.

class are brilliantly flowering plants, such as those of the *Kalmia*, *Ledum*, *Rhododendron*, *Andromeda*, *Arbutus*, *Hydrangea*, *Saxifraga*, *Dianthus* (which includes the carnation, pink, and sweet-william), *Lychnis*, *Stellaria*, *Oxalis*, and *Sedum*.

Digynia.

XI. DODECANDRIA.—There is no plant yet discovered with eleven stamens, and all those of this class have the number varying from twelve to nineteen. The class includes the mangosteen, the garlic-pear, the showy British *Lythrum Sali-*

Pentagynia.



Tetragynia.

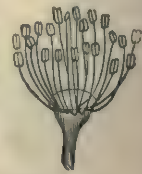
caria, agrimony, *Reseda*, one species of which (weld) is used by the dyer for producing a yellow colour; while another, *R. odorata*, is the mignon-

Monogynia.

Dodecagynia.

ette, *Sempervivum*, or house-leek, *Asarum* or Asarabacca, *Cephalotus*, whose leaves are formed into pitchers, like those of the *Nepenthes*, or pitcher-plant.

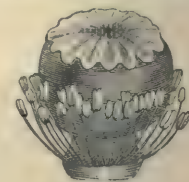
XII. ICOSANDRIA.—Flowers having twenty or more stamens seated upon the corolla or calyx. The situation, and not the number of the stamens, furnishes the characters of the class. It includes the roses, the Cactal genera, *Cereus*, *Epiphyllum*, and *Opuntia;* the myrtle, and its allied genera, *Eugenia* and *Eucalyptus*, the guava, pomegranate, pear, apple, quince, cherry, strawberry, raspberry, &c.



Monogynia.

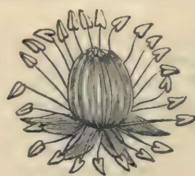
XIII. POLYANDRIA.—Flowers having an unlimited number of stamens, distinct from each other, and seated on the receptacle. This class comprises, among many others, the

Trigynia.



Monogynia.

caper-tree, the poppy, the curious sarracenia, the magnificent water-lilies, the *Bixa orellana* (arnotto),



Polygynia.

Pentagynia.

the magnolia, the pæony, the larkspur, the aconite, the columbine, the anemone, the buttercups, the globe flower, the marsh-marigold, &c.

XIV. DIDYNAMIA.—The flowers of this class are generally ringent; they have four stamens, *two of which are longer than the others.* The flowers of the fourth class have also four stamens, but these are of equal lengths; while in this, two are long and two short. The calyx also is tubular, divided into five or two lipped segments, which are unequal and persistent. The corolla is of one petal; the upper lip concave, and sometimes bifid; the lower lip trifid. In the first order, the so-called GYMNOSPERMÆ, the germander, lavender, mint, dead-nettle, and many others of similar

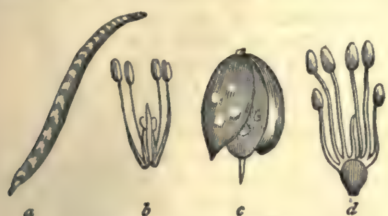
Angiospermæ.

Gymnospermæ.

character occur. The order ANGIOSPERMÆ, so called because, though the stamens are the same

in number and position, the seeds are differently disposed, being contained in a more evident capsule than the preceding. To this order the bignonia, antirrhinum, mimulus, gloxinia, common foxglove (*Digitalis purpurea*), &c. belong.

XV. TETRADYNAMIA.—Flowers with six stamens, four of which are longer than the other two. Linnæus divided this class into two orders—SILICULOSÆ and SILIQUOSÆ—the former being a short roundish pod (*c*), and the latter a long one (*a*). The cabbage, turnip, radish, wallflower, stock, rocket, &c. belong to this class. This is a truly natural class of plants, forming the order *Cruciferæ* of Jussieu; great similarity of the flowers, seeds, &c. being observable throughout the whole of the genera. The calyx is four-leaved,



Stamens and Seed-vessels.

sepals concave, equal, and deciduous; corolla of four petals, claws inserted into the receptacle, limbs widening outwards in a cruciform manner.

XVI. MONADELPHIA.—The stamens are united into one set or brotherhood in this class, which is divided into eight orders, founded on the number

Octandria. Heptandria. Pentandria. Triandria.

of the stamens, not on that of the pistils, as in other classes. In the first order, TRIANDRIA, we find several beautiful Cape bulbs—as the *Tigridia*, *Herbertia*, &c. Of the second order, PENTANDRIA, the passion-flower is the most remarkable. There is also the *Erodium* or stork's-bill, a genus allied to the geraniums. The third order, HEXANDRIA, contains but one genus, a bulbous-rooted plant, called *Gilliesia graminea*, having grass-like leaves and curious flowers. The fourth order, HEPTANDRIA, contains the pelargoniums, commonly called geraniums. The fifth order, OCTANDRIA, having eight stamens, united in one set, contains the genus *Aitonia*, named by Linnæus in honour of the late William Aiton, royal gardener at Kew. In the sixth order, DECANDRIA, we find the true geraniums or crane's-bills. The seventh order, DODECANDRIA, are all tropical plants. In the

Polyandria. Dodecandria. Decandria.

eighth order, POLYANDRIA, are *Althea*, *Lavatera*, *Hibiscus*, *Sida*, silk-cotton tree, the tea-tree, and its magnificent congener, the camellia.

XVII. DIADELPHIA.—Flowers having two sets or brotherhoods of stamens. In general, nine are

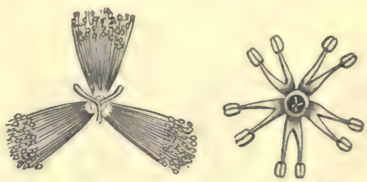
Hexandria. Pentandria.

united together, with a single one by itself, which is accounted the second brotherhood. Examples: *Monnina trifolia*; *Fumaria*, fumitory; and *Poly-*

Decandria. Octandria.

gala, the milkwort, and many leguminous plants—such as the common pea, furze, broom, genista, laburnum, rest-harrow, and lupine.

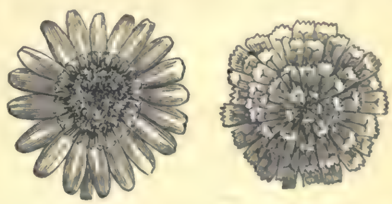
XVIII. POLYADELPHIA.—This class contains all plants whose flowers have their stamens arranged in many brotherhoods. Among the plants of this class is the *Theobroma*, which yields



Polyandria. Decandria.

chocolate. This disposition of the parts on which the order is founded, is exemplified in the species of *Hypericum* or St John's wort.

XIX. SYNGENESIA.—This large class contains all the compound or composite flowers which form the natural order *Compositæ*. The first order is ÆQUALIS, in which all the florets are hermaphrodite. It contains the sow-thistle, lettuce, hawkweed, burdock, artichoke, &c. The second order

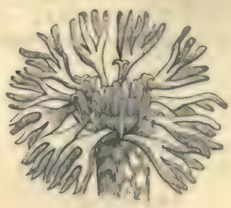


Superflua. Æqualis.

is SUPERFLUA, the flowers of which have the florets of the disc bisexual, and those forming the rays female. This is also a very large order, of which tansy, chamomile, helichrysiums, xeranthemums, dahlias, &c. are examples. The third order is FRUSTRANEA, so called because the florets of the disc are bisexual, and those in the ray or margin neuter. To this belongs the sunflower, the *Rudbeckia*, *Coreopsis*, &c. The fourth

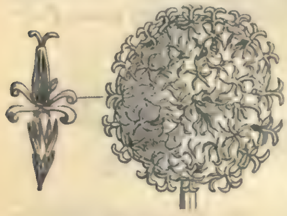
order is NECESSARIA, because the florets of the

Necessaria.



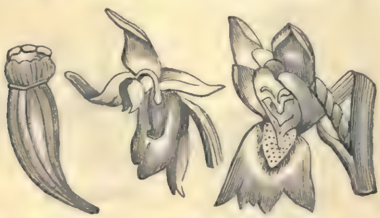
Frustranea.

disc, or centre of the flower, being all male, it is necessary that those of the ray or margin should be female, in order that there may be perfect seed produced. Example: *Calendula*. The fifth order is called SEGREGATA, because the florets have each its proper involucre. All the plants in this order are exotic herbs and under-shrubs, the globe-thistle being the most common in British gardens.



Segregata.

XX. GYNANDRIA.—This class contains plants which have their stamens seated upon the pistil. The class is divided into three orders; the first,



Hexandria. Diandria. Monandria.

MONANDRIA, having one anther seated on the pistil, and comprises *Orchis*, *Ophrys*, *Epipactis*, &c. In the second order, DIANDRIA, the flowers have two anthers on the pistil; to this belongs the ladies'-slipper. The third order, HEXANDRIA, containing plants which have six stamens seated in the pistil, has only one genus—namely, the *Aristolochia*, or birthwort.

XXI. MONŒCIA.—This class (meaning one

Diandria. Monandria.

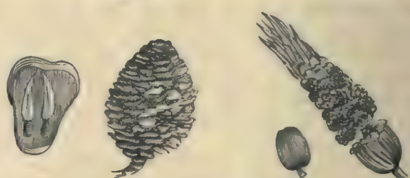
household) consists of plants which have male and female flowers separate, but on the same root—such as the bread-fruit tree, the *Zannichellia palustris*, the maize or Indian corn (*Zea*), the box, the mulberry, the common nettle, the *Aucuba japonica*, the *Amaranthus*, the coco-nut and other palms, *Begonia*, the chestnut, beech, hazel, walnut, oak, pines and firs, larch, cedar, cypress, gourd, melon, and cucumber, the poisonous manihot, the castor-oil, and the cuckoo-pint or wake-robin (*Arum maculatum*). There are ten orders, distinguished by the number and arrangement of the stamens, &c. some of which are illustrated in the wood-cuts. To this class belong the *Carices* or sedges, and also the *Eriocaulon septangulare*.

Triandria. Monandria.

Triandria.

Pentandria. Tetrandria.

Polyandria. Hexandria.



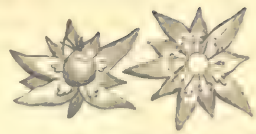
Monadelphia.

XXII. DIŒCIA.—This class is composed of plants which have unisexual flowers, not on the same, but on different individuals, such as the screw-pine, the willow, poplar, crow-berry, date-palm, candle-berry myrtle, sweet gale, spinach, mistleto, hop, hemp, &c. The orders are distinguished by the number, &c. of the stamens, as indicated in the following wood-cuts:

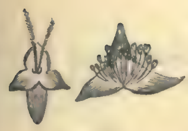
Hexandria. Pentandria.

Enneandria.

Octandria.

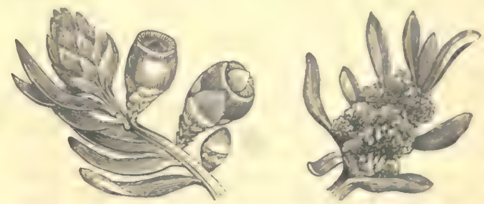


Decandria.



Polyandria.

Icosandria.



Monadelphia.

XXIII. POLYGAMIA.—The class POLYGAMIA (a word signifying many marriages) contains plants having both unisexual and bisexual flowers on the same or on different individuals. There is considerable uncertainty about the arrangement of this division, because some of the genera are not always constant in their modes of flowering; and even single plants will occasionally exhibit all the characters by which the different orders are distinguished. Here are the mimosas, the acacias,

Diœcia.

the maples, the Ailantus, the mango, some palms, the anacardium, and the figs.

XXIV. CRYPTOGAMIA. — The class CRYPTOGAMIA (a term signifying hidden marriages) consists of the flowerless plants corresponding with the class of the same name in the natural system. It is illustrated by ferns, mosses, lichens, fungi, and sea-weeds.

THE NATURAL SYSTEM.

'The Natural System of Botany,' says Dr Lindley, 'being founded on these principles—that all points of resemblance between the various parts, properties, and qualities of plants shall be taken into consideration; that thence an arrangement shall be deduced in which plants must be placed next each other which have the greatest degree of similarity in these respects; and that consequently the quality of an imperfectly known plant may be judged of by that of another which is well known —it must be obvious that such a method possesses great superiority over artificial systems, like that of Linnæus, in which there is no combination of ideas, but which are mere collections of isolated facts, having no distinct relation to each other. The advantages of the Natural System, in applying botany to useful purposes, are immense, especially to medical men, who depend so much upon the vegetable kingdom for their remedial agents. A knowledge of the properties of one plant enables the practitioner to judge scientifically of the qualities of other plants naturally allied to it; and therefore the physician acquainted with the natural system of botany may direct his inquiries, when on foreign stations, not empirically, but upon fixed principles, into the qualities of the medicinal plants which have been provided in every region for the alleviation of the maladies peculiar to it. He is thus enabled to read the hidden characters with which Nature has labelled all the hosts of species which spring from her teeming bosom. Every one of these bears inscribed upon it the uses to which it may be applied, the dangers to be apprehended from it, or the virtues with which it has been endowed. The language in which they are written is not indeed human: it is in the living hieroglyphics of the Almighty, which the skill of man is permitted to interpret. The key to their meaning lies enveloped in the folds of the natural system, and is to be found in no other place.' Such a system as is here eloquently delineated, we aim at rather than possess. All the modifications—and they are neither few nor unimportant—of Jussieu's original plan which have been promulgated, are merely contributions to one great end; and years of patient research, crowned by the most extensive powers of generalisation, must elapse before botany can boast of a perfect system.

According to the original system of Jussieu, all the known plants were arranged into a hundred Orders, beginning with the *Fungi*, and mounting upwards to the *Coniferæ;* and these Orders were divided into three great Classes — namely, the ACOTYLEDONES, or plants without any cotyledon or seed-lobe; the MONOCOTYLEDONES, plants with one cotyledon; and the DICOTYLEDONES, those with two or more cotyledons. The Acotyledonous plants were not subdivided; but the Monocotyledones were arranged into sub-classes, according as the stamens were *hypogynous*, or arising from under the pistil; *perigynous*, or growing from the calyx; and *epigynous*, or arising apparently from above the ovary by adhesion to it. The Dicotyledones were divided into the *apetalous*, or those without petals; the *monopetalous*, those with one petal; and the *polypetalous*, those with several separate

petals; and these again were subdivided, according to the position of the stamens with regard to the pistil, in the same manner as the Monocotyledonous plants. To these were added what Jussieu called *Diclines*, or those plants with separated unisexual flowers. The fault of this system, like that of Linnæus, was that it associated species dissimilar in their nature; the classification depending on one peculiar feature more than on the general appearance, qualities, and habits of the plant.

The system of Jussieu was improved by De Candolle, who at first made 161 orders; but these were afterwards greatly increased, and Lindley enumerates upwards of 300.

The first grand division of De Candolle, like that of Linnæus, is into the Flowering and Flowerless plants, which he designates respectively the *Vasculares* and the *Cellulares*. This division, however, is not absolutely correct; for although all the flowering-plants contain vascular tissue, and the flowerless consist principally of cellular tissue, yet scalariform or ladder-like vessels are common in the ferns and club-mosses. The *Vasculares* and *Cellulares* of De Candolle may be considered as equivalent to the *Phænogamia* and *Cryptogamia* of the older botanists.

His second division depends upon the cotyledons of the embryo; and, like Jussieu, he divides the flowering-plants into DICOTYLEDONES, or those

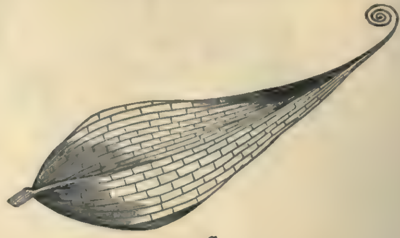
a b b

with two or more cotyledons or seed-leaves, as *a*; MONOCOTYLEDONES, those which have only one seed-leaf (*b*, *b*); and ACOTYLEDONES, those having no seed-leaf, and, in fact, no proper seeds—such as the Cryptogamia. The differences between these three divisions are decided, and are exhibited in different parts of the plant; but they are particularly conspicuous in the leaves—the venation of

a

Dicotyledonous leaves being reticulated, as in the apple (*a*); and that of Monocotyledonous being chiefly in parallel lines, as shewn in the leaf of the Gloriosa (*g*). Dicotyledonous trees are said to be *Exogenous*, from the fact of their trunks increasing by external layers; Monocotyledonous ones, *Endogenous*, on account of the enlargement taking place from within; and Acotyledonous trees, *Acrogenous*, because the increase takes place only at the top or growing-point.

Dicotyledonous plants are divided into the *Dichlamydeæ*, or those with two floral envelopes—that is, having a separate calyx (*a*) and corolla (*b*); and the *Monochlamydeæ*, or those having only one

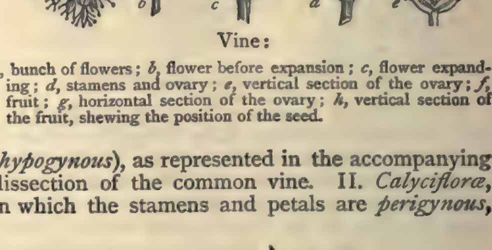


g

floral envelope, which is always called the calyx, as in the detached floret in the wood-cut (*c*).

These distinctions, however, are not always invariable, as many plants in the first division have no corolla, but simply a coloured calyx.

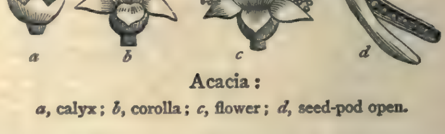
The *Dichlamydeæ* are further divided into three sub-classes: I. *Thalamifloræ*, in which the stamens and petals are all inserted in the receptacle



Vine:

a, bunch of flowers; *b*, flower before expansion; *c*, flower expanding; *d*, stamens and ovary; *e*, vertical section of the ovary; *f*, fruit; *g*, horizontal section of the ovary; *h*, vertical section of the fruit, shewing the position of the seed.

(*hypogynous*), as represented in the accompanying dissection of the common vine. II. *Calycifloræ*, in which the stamens and petals are *perigynous*,



a b c d

Acacia:

a, calyx; *b*, corolla; *c*, flower; *d*, seed-pod open.

inserted in the calyx, as shewn in the preceding dissection of an *Acacia*; or *epigynous*, arising from the upper part of the ovary. III. *Corollifloræ*, in

which the stamens are inserted on the petals, as in the annexed dissection of the acanthus, or in a

Acanthus:

a, corolla opened, shewing the stamens and pistil; *b*, one stamen; *c*, pistil; *d*, ripe seed-vessel, covered with its calyx and bracts; *e*, seed-vessel burst previously to shedding its seeds; *f*, seed opened, shewing the radicle and plume.

few cases on the receptacle, the parts of the corolla being united together. The *Monochlamydeæ* are those having only one, or sometimes no floral envelope.

Monocotyledonous plants are divided into those with petals, called *Petaloideæ*, and those with glumes, as grasses, *Glumiferæ*.

Flowerless or *Cryptogamous* plants are divided into two classes—those formed of a cellular expansion without distinct stem or leaves, which are called *Thallogens* (*a*); and those with leaves (fronds) borne upon a distinct stem or rhizome, *Acrogens* (*b*).

Cryptogamous Plants.

The distinctions between the orders are drawn from the number and arrangement of petals, sepals, and stamens; the construction of the anthers, and the manner in which they burst; the structure of the seed-vessel and of the seeds, with the position of the embryo; the position of the leaves, whether alternate or opposite, or with or without stipules; and the general habits and properties of the plants.

Having thus explained the basis of arrangement, we shall now proceed to consider the ORDERS—premising that while the whole are tabulated, our space will only permit us to detail the more interesting and important ones. This, however, we shall endeavour to do in such a manner as may at once present an outline of the System, and render the reader familiar with the phraseology and plan of procedure.

In this and the subsequent lists of natural orders, those orders marked with an asterisk contain species indigenous in Britain.

EXOGENOUS OR DICOTYLEDONOUS PLANTS.

§ THALAMIFLORÆ.

*Ranunculaceæ—Crowfoots.
Dilleniaceæ—Dilleniads.
Magnoliaceæ—Magnoliads.
Anonaceæ—Anonads.
Schizandraceæ—Schizandra order.
Menispermaceæ—Moonseeds.
Lardizabalaceæ—Lardizabala order.
*Berberidaceæ—Barberry order.
Cabombaceæ—Watershields.
*Nymphæaceæ—Water-lilies.
Nelumbiaceæ—Water-beans.
Sarraceniaceæ—Water-pitchers.
*Papaveraceæ—Poppy order.
*Fumariaceæ—Fumeworts.
*Cruciferæ—Crucifers.
Capparidaceæ—Capparids.
*Resedaceæ—Weldworts.
Flacourtiaceæ—Arnotto order.
*Cistaceæ—Rock-roses.
*Violaceæ—Violets.
*Droseraceæ—Sun-dews.
*Polygalaceæ—Milkworts.
Krameriaceæ—Rhatany order.
Tremandraceæ—Poreworts.
*Tamaricaceæ—Tamarisks.
*Frankeniaceæ—Frankeniads.
*Elatinaceæ—Water-peppers.
*Caryophyllaceæ—Cloveworts.
Vivianiaceæ—Viviania order.
*Malvaceæ—Mallowworts.
Sterculiaceæ—Silk-cottons.
Byttneriaceæ—Chocolate order.
*Tiliaceæ—Lindenblooms.
Dipteraceæ—Dipterads.
Chlænaceæ—Chlænads.
Ternströmiaceæ—Tea order.
Olacaceæ—Olax order.
Icacinaceæ—Icacina order.
Cyrillaceæ—Cyrilla order.
Aurantiaceæ—Orange order.
*Hypericaceæ—St John's worts.
Guttiferæ—Guttifers.
Marcgraviaceæ—Margraviads.
Hippocrateaceæ—Hippocrateads.
Malpighiaceæ—Malpighiads.
Erythroxyleæ—Redwoods.
*Aceraceæ—Maples.
Sapindaceæ—Soapworts.
Rhizobolaceæ—Suwarrow-nuts.
Meliaceæ—Meliads.
Humiriaceæ—Humirium order.
Cedrelaceæ—Mahogany order.
Vitaceæ—Vineworts.
*Geraniaceæ—Cranes'-bills.
*Linaceæ—Flaxworts.
*Oxalidaceæ—Wood-sorrels.
*Balsaminaceæ—Balsams.
Tropæolaceæ—Indian Cresses.
Limnanthaceæ—Limnanthids.
Pittosporaceæ—Pittosporum order.
Brexiaceæ—Brexia order.
Zygophyllaceæ—Bean-capers.
Rutaceæ—Rueworts.
Xanthoxylaceæ—Prickly-ash order.
Ochnaceæ—Ochnads.
Simarubaceæ—Quassia order.

RANUNCULACEÆ.—The plants constituting this order are herbs, or rarely shrubs, with generally deeply cut, rarely stipulate leaves, and stem-clasping petioles. The majority of the species are hardy, and abound in an acrid poisonous juice, as is well exemplified in the common buttercups of the meadows, belonging to the genus *Ranunculus*, from which the order takes its name. The plants of the order are very variable in their flowers; many of them having merely one floral envelope, and others having a coloured calyx, with only very small and inconspicuous petals. When the flowers are regular—that is, when the parts are all of one size—the corolla consists generally of five petals, and the calyx of five sepals, though the number of the petals sometimes varies from three to fifteen. There are numerous stamens which grow from beneath the pistil, and are always separate, having their anthers bursting outwardly. The seeds are for the most part contained in carpels which are separate. The embryo is very small, and placed at the base of the albumen, which is either fleshy or bony. In consequence of the variable character of their flowers, the *Ranunculaceæ* are somewhat perplexing to the learner, though they may be generally known by their numerous distinct stamens springing from below the pistil, and by their distinct carpels, which frequently grow in several whorls round an elevated receptacle, as in the crowfoot and pheasant's-eye. The calyx generally falls off with the petals, but in the pæony it remains till the seed is ripe. The carpels are in many cases only one-seeded, and are sometimes winged, as in the anemone and clematis, in order to scatter the seeds, as the carpels in this case do not open naturally, but fall with the seed.

Sometimes, however, the carpels are many-seeded, and open naturally when ripe, as in the pæony, the larkspur, the columbine, &c. The principal genera —which lie within the examination of every one— are the Ranunculus and Pæony, having regular flowers and two floral envelopes; the Anemone, the Hepatica, the Christmas Rose, and the winter Aconite, which have regular flowers, but generally only one floral envelope; and the Larkspur, Monkshood, and Columbine, which have irregular flowers. The Clematis is one of the few shrubby plants belonging to the order; it has regular flowers, and generally only one floral envelope. The *Ranunculaceæ* are of little economical importance. The juice of the whole order is acrid, the roots of many intensely bitter, and the bark of a few tonic and bitter. The seeds of the Nigella are aromatic, and were formerly used as pepper; but those of all the other genera are poisonous, unless husked. The flowers of some are objects of great beauty—as the larkspurs, ranunculuses, anemones, pæony, and columbine. The 'lesser celandine' of Wordsworth (*Ranunculus Ficaria*) has been used as an article of food in Austria, its small farinaceous tubers resembling peas. But most of the plants belonging to the order are acrid and poisonous, some of them eminently so. *Ranunculus arvensis* is one of the most dangerous farm-weeds which the agriculturist has to fear; but the monkshood (*Aconitum Napellus*) exceeds them all in virulence, and has been the cause of distressing accidents, from its root being mistaken for horse-radish. We read in classic story how the Roman stepmothers of old employed this root to poison their adopted children; and a nearly allied species has derived notoriety from having been employed by the Nepaulese to poison their wells against the approach of an enemy.

DILLENIACEÆ.—This order consists of woody plants having astringent qualities. Some of them yield excellent timber. They are chiefly confined to Australasia, India, and equinoctial America.

MAGNOLIACEÆ.—This order consists of woody plants remarkable for the beauty of their foliage and the fragrance of their flowers, of which the common Magnolia of gardens is a familiar example: they have bitter, tonic, and aromatic qualities. Winter's Bark (*Drimys Winteri*), and the tulip-tree of America (*Liriodendron tulipifera*), belong to the order.

BERBERIDACEÆ.—Plants of temperate and warm countries in both hemispheres, represented in Britain by the common barberry of our hedgerows, the stamens of which display irritability when touched near the base. According to the late Sir J. Y. Simpson, the roots of several species furnish the astringent matter called Lycium by Dioscorides. *Berberis dulcis* yields a table-fruit.

NYMPHÆACEÆ.—Gigantic aquatic herbs, with a thick rhizome in the mud, giving off large floating leaves on long petioles. The rhizomes exhibit a structure resembling that of endogenous plants; but the embryo is truly dicotyledonous. Water-lilies appear to occur in most parts of the world, except cold regions. The white water-lily (*Nymphæa alba*) is one of the greatest ornaments of the English and Scotch lakes; while the yellow one (*Nuphar lutea*) more commonly occurs in slow streams and pools. *N. pumila* is rare. The most magnificent of all is the *Victoria regia*, the royal water-lily of South America, whose size, in keeping with the gigantic proportions of the Amazons and Essequibos, on whose waters it displays its beauty, is unrivalled in the vegetable kingdom. Its floating leaves are two yards across, continuously covering miles of surface with their verdure, each having a turned-up margin like a tea-tray. The flowers are a foot across, formed of hundreds of petals of the most delicate rose-colour, and exhale a delicious perfume in the evening as they expand.

PAPAVERACEÆ.—This order consists of very handsome herbaceous plants, annual and perennial, most of which are natives of the temperate parts of Europe and Asia. The leaves are alternate, sometimes deeply cut, and without stipules. The flowers are solitary, elevated on long peduncles, showy, and usually white, yellow, or red; and the bud in all, except the large scarlet Eastern poppies, is shrouded in only two sepals, which fall off as soon as the flower expands. The Oriental species have three sepals, and one of them (*Papaver bracteatum*) has two large bracts which remain after the flower has expanded, and form a kind of calyx, though the real calyx has dropped off. There are generally four petals, or a multiple of four, which are crumpled in the bud, and soon fall off. The stamens are very numerous, inserted in four or more whorls beneath the pistil (*a*). The ovary is solitary, forming a capsule, which consists of several carpels grown together; stigmas generally stellate on the flat apex of the ovary. Notwithstanding the fleshy ovary, the fruit is a dry capsule, with only one cell, the divisions between the carpels having disappeared. The seeds are numerous, have a minute straight embryo, imbedded in albumen, and become loose in the capsule when they are ripe. Before the seeds are ripe, the walls of the capsules become as hard as a shell; and the stigmas, which are grown together, and become equally hard, form a star-shaped lid for the capsule (*b*). Under this there is a set of valves that open for the discharge of the seed.

Papaver somniferum.

The British genera are—*Papaver*, the poppy, of which there are five native species; *Meconopsis*, Welsh poppy; *Glaucium*, horned poppy; *Chelidonium*, greater celandine or swallow-wort. There are many more, however, grown in our gardens as ornamental plants, such as *Sanguinaria*, or bloodroot; *Argemone*, the prickly poppy; *Eschscholtzia; Rœmeria; Hypecoum; Platystemon;* and *Platystigma*. In the horned poppy, the seed-vessel is formed of two carpels grown together, which look like a pod; and when ripe, from their length and stiffness, bear a considerable resemblance to a horn; hence the name. The *Sanguinaria* has a red juice; the greater celandine, as well as the prickly poppy, has a yellow juice—the juice of the others is white. In the Eschscholtzias

the sepals do not separate; but becoming detached at the base, they retain the shape of a hood or extinguisher, till pushed off by the expansion of the corolla. The capsules of the Eschscholtzias are elongated, and are easily known by the large fleshy projection at their base. The plants of the order are easily detected by their general resemblance to each other, especially in their flowers.

All the Poppyworts abound in a thick glutinous juice, which poisons by stupefying. All parts of the plant furnish more or less this milky sap, but the main supply is derived from the unripe seed-vessels. When in a green state, those of the large white poppy (*P. somniferum*) are slightly wounded with a knife, which causes the juice to exude freely; and on exposure to the air, it concretes or becomes inspissated. In this state, it forms crude or lump opium, which, dissolved in spirit of wine, and filtered, produces the laudanum of the shops. Chemically, opium consists of an insoluble gum, a small quantity of resin, and caoutchouc. Its effects on the animal system depend upon two alkaline principles which it contains—namely, morphia and narcotine; the former producing a sedative, and the latter a stimulating effect. It is curious that the seeds possess none of the stupefying properties of the plant, but are mucilaginous and oily, and may be eaten with impunity. The seeds of one species, however (*Argemoné Mexicana*), are said to be narcotic, especially when smoked; but it is probable that in this case the opiate resides in the coating of the seed rather than in the albumen.

CRUCIFERÆ.—This is one of the most extensive and important of the natural orders. Most of the genera are herbaceous annuals and perennials. The leaves are alternate, and the flowers are produced in corymbs or racemes, being usually regular, with a calyx of four sepals, and a corolla of four petals, disposed in the form of a Maltese cross: hence the name *Cruciferæ*, or cross-bearing. There are six stamens, two much shorter than the others, as shewn under the Linnæan class *Tetradynamia*. The pods open naturally when ripe, the valves curling outwards, as in the common cabbage or wallflower, for example. The seeds have no albumen, and the cotyledons are curiously folded down on the radicle. There can be no difficulty in recognising a cruciferous plant when it is in flower, by the cross form of its corolla, as in the preceding figure, and its six stamens, two of which are shorter than the others.


Crucifer.

Among the more common genera may be mentioned *Brassica*, including the cabbage and turnip; *Cheiranthus*, the wallflower; *Mathiola*, the stocks; *Iberis*, the candy-tuft; *Isatis tinctoria*, the woad; *Armoracia*, the horse-radish; *Sinapis*, the mustard; *Raphanus*, the radish; and many other well-known plants. The plants are generally distributed, but abound in cold and temperate regions. There are about 1700 known species.

The properties of the Crucifers are antiscorbutic and pungent, combined with an acrid flavour; and the seeds of many abound in a fixed oil: properties of which the common cress, mustard, and rape may be taken as examples. Most of them form articles of human food, and are valuable not only for their antiscorbutic properties, but from the fact that they contain a large amount of nitrogen. All the cultivated varieties of turnip appear to have been derived from *Brassica Rapa*, which occurs in a wild state in Britain.

MALVACEÆ.—All the plants belonging to this natural order bear a striking resemblance to each other, and have large showy flowers. The petals and sepals are each five in number, but the calyx has three bracts on the outside, having the appearance of a second calyx below the true one. Æstivation twisted. The most remarkable part of the flower is the central column, and this is so decided, that a botanist is always able to recognise one of the Malvaceæ at first sight. This column is formed by the filaments of the stamens growing together, so as to leave only a small portion just below the anthers free, as is seen in the flower of the marsh-mallow—the lower portion forming a tube round the pistil. The anthers are one-celled, kidney-shaped, and burst transversely, opening inwardly. This peculiar construction of the stamens may be observed distinctly in the mallows, the hollyhocks, and, in short, in all the genera belonging to the order. The styles also grow together, as may be seen when the stamens are removed; and the carpels, which are of the same number with the styles, form what children call 'mallow cheeses.' The carpels are one or many seeded, sometimes closely united, sometimes separated or separable; fruit capsular or baccate. Most of the species are herbaceous plants; several, trees or shrubs. Leaves alternate, more or less divided and stipulate, often covered with stellate hairs. The plants abound in tropical regions and in the hotter parts of the temperate zone.


Marsh-mallow.

The economical uses of the order are highly important. Cotton, on which so much of British commerce depends, is obtained from several species of *Gossypium*, and is the downy hairs which are attached to and envelop the seeds. These hairs, originally of a cylindrical form, at maturity become collapsed into flat bands, and are much twisted. Much confusion exists in botanical works relative to the species of Gossypium, the varying character of the plants having, it is feared, given rise to unnecessary names. The researches of Royle seem to indicate that all the forms known in commerce should be reduced to four species of plants—namely, 1. *Gossypium herbaceum*, which is the common cotton-plant in India, and a variety of which, with buff-coloured hairs, supplies the Nankin cotton. 2. *G. arboreum*, the tree-cotton of India, with red flowers and a fine silky cotton. 3. *G. Barbadense*, Barbadoes cotton, called in India Bourbon cotton, which supplies the highly esteemed Sea Island cotton, as well as the Georgia and New Orleans cottons. 4. *G. Peruvianum*, Cavanilles (or *G. acuminatum*), which supplies the Pernambuco or Brazil cotton. The great difference in the value of different kinds of cotton depends chiefly upon the length of staple, precise measurements of which have recently been published by the United States government.

The inner bark of *Hibiscus cannabinus* furnishes a kind of sun-hemp in India. *H. mutabilis* has

showy flowers which change colour, passing in the course of the day from a cream-coloured rose to a delicate pink or rich rose. *H. tiliaceus* yields Cuba-bast. The tree-mallow (*Lavatera arborea*) grows on rocks exposed to the influence of the sea, as on the Bass Rock and Ailsa Craig. Various species of *Sida* furnish fibre. *S. Phyllanthos* and *S. Pichinchensis* ascend, on the mountain of Antisana and the volcano Rucu-Pinchincha, to the elevation of 13,000 or 15,000 feet.

Many of the Malvaceæ are also medicinal and dietetic. The *pâte de Guimauve*, which is made from a species of marsh-mallow, is used on the continent in disorders of the lungs; from the *Althæa officinalis* is prepared, in France, the vegetable tracing-paper known by the name of *papier végétal;* and a blue matter, not inferior to indigo, is obtained from the leaves of the hollyhock (*A. rosea*). The Chinese blacken their eyebrows with the flowers of *Hibiscus Rosa-sinensis*, and Europeans apply it to the less honourable purpose of blacking their shoes.

TERNSTRÖMIACEÆ.—This is one of the most interesting natural orders, as, besides other fine plants, it contains the camellias and tea-trees. All the members are trees or shrubs, with very handsome flowers. The leaves are alternate, and without stipules; they are frequently leathery, and are sometimes marked with pellucid dots. The flowers have generally five sepals and five petals; sometimes there are two additional sepals a little below the others. The stamens are numerous, and either grow together into a central column, or are in five distinct bundles. There are but few seeds, which are large, and entirely filled with an embryo having thick cotyledons like the bean, and no albumen.

Only a very few genera belonging to this order have been introduced into this country; but there are a number of equally beautiful species found in the East Indies and South America. Those best known in Britain are the genera *Gordonia*, *Stuartia*, *Camellia*, and *Thea*. The common camellia—*C. Japonica*—is too well known to need any description, and its beautiful flowers and thick glossy leaves must be familiar to every one. The double varieties are numerous, but the 'old double white,' as it is called, is still the favourite kind for ballroom decoration. The tea-tree is very nearly allied to the camellia, but its flowers and leaves are smaller. The teas of commerce are obtained from two different plants, named respectively *Thea Bohea* and *Thea viridis*, on the supposition that the former produced our ordinary black teas, while the latter afforded *green* tea. However, both kinds of tea are manufactured from either plant, the difference mainly depending on the time of gathering and the mode of preparation. The young leaves, quickly dried and subjected to a particular kind of manipulation, form green tea; while the older ones, dried more slowly, and undergoing fermentation, constitute black tea; but in some cases the green colour is imparted by means of a mixture of turmeric, Prussian-blue, and gypsum.

Long confined to China, this branch of Oriental agriculture has at length been successfully introduced into India. The Assam Tea is furnished by a larger plant than either of the preceding, which is now regarded as a distinct species, *T. Assamica.*

AURANTIACEÆ.—The golden fruit of the orange and lemon, so characteristic of this order, is so beautiful, that it is supposed to have been typified by the celebrated apples of the Hesperides. The order consists of elegant and fragrant trees or shrubs. The leaves, though apparently simple, are compound, because they are articulated with the petiole, which in the orange and some other

Lemon.

species is winged. The calyx is tubular, with five short teeth. The petals of the corolla are five in number, thick and fleshy, and when held up to the light, they appear full of pellucid dots, which are receptacles of secretion filled with fragrant oil. There are generally twenty stamens, which are divided into five bundles, the filaments in each bundle adhering together. The fruit—hesperidium, as it is called by botanists—is divided into numerous cells by dissepiments, and there is a central placenta, to which the ovules are attached in the ovary; but as the fruit swells, the seeds become detached, and the cells fill gradually with cellular tissue, till at last they become replete with an acid and bitter pulp, in which the seeds are immersed. The seeds are exalbuminous, and sometimes contain more than one embryo.

The most familiar genus is *Citrus*, the species of which are chiefly natives of the tropics—most of them being found in a wild state exclusively in the East Indies. The orange, however, appears to have an extraordinary facility of adapting itself to any country the climate of which is dry and sunny; and thus have arisen the orange groves of St Michael and of Florida, besides those of Malta, and various parts of Europe and North Africa. All the kinds of orange, lemon, shaddock, citron, &c. belong to the genus *Citrus. C. Aurantium* is the sweet orange, so generally cultivated. The principal kinds are the common orange, the Chinese or Mandarin, the Maltese, and the St Michael. *C. medica* is the citron; *C. Limonum*, the lemon; *C. Limetta*, the sweet lime; and *var. Bergamia*, the bergamot; *C. Paradisi*, the forbidden fruit; and *C. decumana*, the shaddock. The Wampee, the fruit of *Cookia punctata*, is much admired in China and the Indian Archipelago. *Ægle Marmelos*, the Indian Bael or Bela, yields a delicious fruit.

All the Aurantiaceæ abound in a fragrant oily matter, which is contained in the receptacles of secretion in the rind of the fruit, and in the leaves

of the tree. The pulp of the fruit is more or less acid. About 35,000 tons of oranges are said to be annually imported into Great Britain. The productiveness of the common orange is enormous: a single tree at St Michael has been known to produce 20,000 oranges fit for packing, exclusive of the damaged fruit and the waste, which may be calculated at one-fifth more.

SAPINDACEÆ.—The Soapworts are woody, rarely herbaceous plants, with usually compound leaves and unsymmetrical flowers, most of them being found in the hot parts of India and America, and little known in Europe, except from the writings of travellers. This remark will not apply, however, to the *Hippocastaneæ*, or horse-chestnuts (distinguished by their opposite leaves, and by the ovary having two ovules—one erect, the other suspended—in each cell), which are natives of Northern India, Persia, and the American States. This section consists of only two genera—namely, *Æsculus*, the horse-chestnut; and *Pavia*, the scarlet-flowering chestnut. The leaves are palmate

Æsculus Hippocastanum.

—that is, divided into five or seven parts; and are without stipules. The flowers are produced in large panicles or racemose cymes. There are five petals, two of which are smaller than the others, and all have small claws. In the *Pavia* there are only four petals, two of which are so much smaller than the others as to look like leafy stamens. There are seven stamens, three of which are much shorter than the others. The fruit of the horse-chestnut consists of a leathery capsule, which opens when it is ripe into three valves. The capsule of Pavia is smooth. The scar of the hilum is very strongly marked on the testa of the nuts of both genera; and in Pavia it is so conspicuous as to give rise to the American name of the genus, which is called *Buck's-eye*, from the resemblance of the hilum to the pupil of an eye. The horse-chestnuts have been so long cultivated in Europe as now to spring up like natives of the soil. Both of the genera are amongst the finest of our flowering-trees, and on this account are common in park-scenery. The seeds of the order abound in starchy and in saponaceous matter. The bark of the common *Æsculus Hippocastanum* is bitter, astringent, and has been recommended as a valuable febrifuge in intermittent and other fevers. The Akee fruit (*Blighia sapida*); the Li-chi (*Nephelium Litchi*) and Longan (*N. Longan*), fruits of China; the Guaraná plant (*Paullinia sorbilis*) of India, and the soap-berry (*Sapindus saponaria*), all belong to the order.

VITACEÆ.—This order comprises about 260 species, natives of temperate climates. Their prevailing habit is a long dangling growth of stem, with tendrils opposite the leaves, thyrsus of colourless flowers, and bunches of berried fruit. The stem and branches are furnished with tumid articulated nodes; the leaves are lobed or compound, generally alternate with stipules. The flowers are small, often the male and female distinct; calyx, very small; sepals and petals, four or five, the latter sometimes cohering at the tips, and falling off before the bursting of the anthers; stamens, equal in number to the petals, and opposite to them; ovary, two-celled; fruit, a berry, with the seeds immersed in pulp; seeds with a bony testa; albumen, hard; embryo, small. The curious formation of the flower and berry is well illustrated by the dissection of the common vine, as shewn in page 88.

The genera are—*Ampelopsis*, the vine-leafed ivy; *Vitis*, the grape-vine; *Leea*, *Cissus*, *Pterisanthes*, and *Rhaganus*. With the exception of the vine, the other genera are of little interest, being employed only as ornamental creepers. The grape-vine is said to be a native of the shores of the Caspian, whence it has been widely distributed, and greatly improved by cultivation.

The properties of the fruit, either in its fresh state or dried to form raisins, or expressed and fermented to form wine, &c. are too well known to require description. The average import of raisins to Britain amounts to more than 12,000 tons, the finest being the Muscatel. The dried currants of commerce—a corruption of Corinths—are the produce of the small seedless Corinthian grape, which is cultivated in many islands of the Mediterranean. Currants are annually imported to the extent of 21,000 tons. *Vitis vulpina* is a kind of wild vine which produces what are called fox-grapes in North America; it forms an ornamental creeper, being hardy in Britain; and has recently attracted notice as likely to form a good stock on which to graft our grape-vines. The Kangaroo Vine of Australia, which is well suited as an indoor window-creeper, is a species of *Cissus*. The berries of the Virginian creeper (*A. hederacea*) are small and unpalatable, but might be eaten with perfect safety. According to Von Martius, the leaves and fruit of *C. tinctoria* abound in green colouring-matter, which soon becomes blue, and is highly esteemed by the natives of Brazil as a dye for cotton fabrics. Acid leaves, and a fruit like that of the common grape, are the usual characters of the order.

GERANIACEÆ.—The *Geraniaceæ* comprise about 500 species. They are herbs or shrubs, with stems which are tumid and articulated at the joints. The leaves are generally lobed, and furnished with small stipules. Calyx persistent in five-ribbed sepals, sometimes spurred. Corolla generally of five petals, with strongly marked veins. Stamens twice as many as the petals; filaments slightly united at the base. Fruit consists of five elastic one-seeded carpels, adhering to an elongated central axis, from which they curve upwards, by means of the elastic styles, when ripe. Seed without albumen; cotyledons rolled up or folded.

The chief genera are *Geranium*, *Pelargonium*, and *Erodium*, respectively crane's-bill, stork's-bill, and heron's-bill, from the fancied resemblance of the ripe seed-vessel to these objects. Many of the species, which are very widely distributed, are natives of Europe; but the majority of our green-house favourites are from the Cape of Good Hope. The herb Robert (*G. Robertianum*) and the meadow crane's-bill (*G. pratense*) are British plants, as are also *Erodium cicutarium* and *moschatum*. All the pelargoniums have their flowers in heads or umbels, and the calyx remains till the seeds are ripe. Their leaves vary very much, some being round—as the horseshoe geranium—and marked with a dark line; and others are deeply lobed, as some of the scented varieties.

The Geraniaceæ are all innocuous plants, being generally slightly acid, and sometimes astringent. They are all more or less fragrant, secreting oils and resins; and in some these secretions are so abundant (*Monsonia spinosa*) that the stems burn like torches, and emit an agreeable odour during combustion. In America, the roots of *G. maculatum* are used as a remedy for diarrhœa; the British Erodiums are sometimes employed as aromatic bitters; from *P. odoratissimum* a fragrant oil has been distilled, resembling the attar of roses; the underground tubercles of *P. hirsutum* are esculent, and prized by the Arabs as food; the tubers of *G. parviflorum* are eaten by the natives of Tasmania, where it is called the Native Carrot. The pelargoniums, generally called geraniums, which are seen at horticultural exhibitions are chiefly hybrids and improved varieties of the Cape species of *Pelargonium*.

LINACEÆ.—A small order. The flowers are in five parts, like those of the cloveworts; but the sepals of the calyx are always distinct, and, instead of being arranged in a regular whorl, two are placed a little lower than the others, as in the *Cistaceæ*. There are five styles and stigmas; but the seed-vessel splits into ten valves, each carpel containing two seeds, separated by an obscure partition, which gives the carpels the appearance of being only one-seeded. The seeds are flat and shining, with a large embryo.

The only genera are *Linum*, *Cliococca*, and *Radiola;* the former comprehending many species. *L. catharticum* is the purging-flax of rural practice. But of all plants of the order, the common flax (*L. usitatissimum*) is the most important and best known. Flax will grow in almost any part of the world; and though an annual, its stem contains so much woody fibre that it is exceedingly tough and durable, yielding by maceration the flax of commerce. The seeds contain a great quantity of oil (*linseed-oil*), which is obtained from them by pressure, and the refuse forms *oil-cake*, employed by farmers in feeding cattle. The seeds also abound in mucilaginous matter, and are thus made use of medicinally, for coughs, &c.; or, when ground into meal, for poultices. Though lint was at one time pretty extensively grown in Britain, our manufacturers now derive the greater part of their supplies from the countries adjoining the Baltic, from which, in one year, not less than 70,000 tons of flax, and about 2,000,000 bushels of linseed, have been imported. The Valley of the Nile, anciently celebrated for its fine linen, now yields but an inconsiderable quantity, in consequence of the present barbarous condition of the inhabitants. It is there cultivated during the cold season. Of late years, the fibres of flax, by being steeped in a solution of carbonate of soda, and afterwards dipped in a weak acid solution, are so broken up as to form a substance like cotton, which is manufactured in the same way as that fabric.

§ CALYCIFLORÆ.

The plants comprised in this sub-class are dichlamydeous—that is, having both calyx and corolla—as in the preceding; the petals are usually separate, but sometimes united; the stamens perigynous, arising from the calyx, and thus surrounding the ovary; or epigynous, arising, apparently, from the upper part of the ovary, which is in this case inferior as regards the parts of the flower. It has been separated into two divisions: the one named *Polypetalæ*, from the petals being several and separated; the other *Monopetalæ*, from their being so united as to appear single; for example, a wild rose has five distinct petals, separate to the base, whereas a bell-flower (Campanula) has all its petals united into one piece. In no case do the stamens arise directly from the thalamus, which is the characteristic of the preceding sub-class. Here the parts of the flower are more or less united to each other. The following are the orders belonging to Calycifloræ:

POLYPETALÆ.

Stackhousiaceæ—Stackhousiads.
*Celastraceæ—Spindle-trees.
*Staphyleaceæ—Bladder-nuts.
*Rhamnaceæ—Buckthorns.
Anacardiaceæ—Cashews.
Amyridaceæ—Myrrh order.
Connaraceæ—Connarads.
*Leguminosæ or Fabaceæ—Leguminous Plants.
Moringaceæ—Moringas.
*Rosaceæ—Rose order.
Calycanthaceæ—Calycanths.
*Lythraceæ—Loosestrifes.
Rhizophoraceæ—Mangroves.
Vochysiaceæ—Vochysia order.
Combretaceæ—Myrobalans.
Melastomaceæ—Melastomads.
Alangiaceæ—Alangiads.
Philadelphaceæ—Syringas.
Myrtaceæ—Myrtles.
Chamælauciaceæ—Fringe-myrtles.
Lecythidaceæ—Monkey-pots.
Barringtoniaceæ — Barringtonias.
*Onagraceæ — Evening Primroses.
*Halorageaceæ—Mare's-tails.
Loasaceæ—Chili-nettles.
*Cucurbitaceæ — Cucumber order.
Papayaceæ—Papaw-worts.
Belvisiaceæ—Belvisiads.
Passifloraceæ—Passion-flowers.
Turneraceæ—Turnera order.
*Portulacaceæ—Purslanes.
Illecebraceæ—Knotworts.
*Crassulaceæ—Stonecrops.
Mesembryanthemaceæ — Fig-marigolds.
Tetragoniaceæ—Tetragonias.
Cactaceæ—Cactuses.
*Grossulariaceæ—Gooseberry order.
Escalloniaceæ—Escalloniads.
*Saxifragaceæ—Saxifrages.
Hydrangeaceæ—Hydrangeads.
Cunoniaceæ—Cunoniads.
Bruniaceæ—Bruniads.
Hamamelidaceæ—Witch-hazels.
*Umbelliferæ or Apiaceæ—Umbel-bearers.
*Araliaceæ—Ivyworts.
*Cornaceæ—Cornels.

MONOPETALÆ.

*Loranthaceæ—Mistleto order.
*Caprifoliaceæ—Honeysuckles.
*Rubiaceæ—Cinchona and Bedstraw order.
*Valerianaceæ—Valerians.
*Dipsaceæ—Teazelworts.
Calyceraceæ—Calycera order.
*Compositæ or Asteraceæ—Composites.
Brunoniaceæ—Brunoniads.
Goodeniaceæ—Goodeniads.
Stylidiaceæ—Styleworts.
*Campanulaceæ—Bell-flowers.
*Lobeliaceæ—Lobeliads.
Styracaceæ—Storax order.
Columelliaceæ — Columellia order.
*Vacciniaceæ—Cranberries.

LEGUMINOSÆ.—This is one of the most extensive and best defined orders in the vegetable kingdom. Many of its plants bear butterfly-shaped (papilionaceous) flowers, and all have pod-like seed-vessels; among which may be mentioned, as familiar examples, the pea, bean, lupine, broom, furze, and laburnum. The following may be stated

as the general characteristics of the *Leguminosæ:* Herbs, shrubs, or trees; leaves, alternate, generally compound, their petioles tumid at the base, where there are usually two stipules, and also two to each leaflet in the pinnate leaves; the pedicles are generally articulated, and the flowers are furnished with small bracts; calyx, five-parted, the segments being sometimes unequal and variously combined; petals, never more than five, but often less, and sometimes wanting, inserted into the base of the calyx, and variously arranged, papilionaceous in all European genera, the odd petal being always superior; stamens, definite or indefinite, inserted with the petals, in exceptional cases apparently hypogynous, thus shewing a transition from the preceding sub-class, distinct, or in one, two, or three bundles; ovary, superior, for the most part one-celled; ovules, one or many; style and stigma, simple; fruit, a true legume, a modified form of legume or loment, or sometimes, when containing only one seed, drupe-like; embryo, straight, with or without albumen; the radicle, in some instances, bent along the edge of the cotyledons.

Papilionaceous Flower.

The plants belonging to the order are found in all parts of the world, but they are most abundant in warm regions, and diminish on approaching the poles. There are above 6500 known species.

This family is amongst the most important to man, whether as affording objects of beauty, of utility, or of nutriment. The bean, the pea, the vetch, and the clover tribe belong to it; as do the logwood, the laburnum, indigo, the tamarind, liquorice, senna, and the acacias. Its general properties are considered by some to be wholesome, but there are several exceptions. Thus, the seeds of laburnum, and the juice of *Coronilla varia*, are poisonous. Senna, obtained from various species of cassia, is purgative, and several others of the order possess a similar property. The pericarp of some contains much tannin; dyes are obtained from others; and many yield gums and balsams. It would occupy pages to enumerate all the uses to which this, one of the most extensive orders in the vegetable kingdom, has been applied. We shall, therefore, briefly indicate the principal sections of the order, and the more important plants contained in each.—§ I. *Papilionaceæ*, petals papilionaceous, imbricate, upper one exterior. This, which may be called the Pulse section, is the only one containing British species, but these are numerous, and contribute much to the beauty of our Flora. The vetches and lathyrus, the rest-harrow, the trefoils and clovers, the lotus and the meliloti, are all gay flowers which we gather in our rural walks. Turning to plants of utility, we find here the bean and the pea, the clovers, vetches, sainfoin, and lucerne. The lentil (*Ervum lens*), although a crop of the most ancient cultivation, has only recently been introduced to the notice of British farmers; and may possibly be of some service on light soils. Kidney-beans and scarlet-runners also belong to the garden Papilionaceæ, the latter affording a characteristic illustration of the miscellaneous properties of this order, its roots being poisonous, while its seeds form an article of food. Other plants of the section are decidedly poisonous, such as *Coronilla varia*, and the seeds and bark of laburnum, which, being a common ornamental tree, and one which seeds freely, is apt to give rise to accidents, especially in the case of children. But perhaps the most remarkable of all poisonous species is the ordeal bean of Calabar, *Physostigma venenosum*. It is commonly used in Calabar in trials by ordeal, the suspected party being set free if (by vomiting) the bean does not prove fatal. In like manner, the bark of another species is used by the Caffres as a test in judicial trials. Of miscellaneous plants used in the arts, we find *Astragalus gummifer* and other species, from which gum-tragacanth is obtained; *Baptisia tinctoria*, a dye-plant and the wild indigo of America; *Crotalaria juncea*, whose fibrous bark yields Bengal hemp; *Dalbergia Sissoo*, which in India yields the valuable timber well known by its native name of Sissoo; *Dipterix odorata*, whose fragrant seeds are the Tonka-beans of commerce; *Glycyrrhiza glabra*, whose root forms liquorice; various species of *Indigofera*, from which the true indigo is obtained; *Pterocarpus santalinus*, the source of red sandal-wood; *P. draco*, which yields gum-dragon; and *Triptolomea*, from species of which the rose-wood of commerce appears to be derived. Kino is supplied by various species of *Pterocarpus*, and by *Butea frondosa*, one of the most gorgeous plants of India, with masses of bright orange-red flowers, resembling sheets of flame.—§ II. *Cæsalpinieæ*, petals imbricated, upper one interior. The plants of this section are chiefly important from yielding valuable timbers and dyes, while some are much used as purgative medicines. Of the latter, the various kinds of senna, consisting of the leaves of species of *Cassia*, are most important. The fruit of the tamarind likewise contains a laxative pulp, as also *Cassia Fistula*. Of dyes we have the sappan of India (*Cæsalpinia sappan*), the barwood or camwood (*Baphia nitida*), and the well-known logwood (*Hæmatoxylon campechianum*). Of timber-trees, the Brazil-wood of commerce (*Cæsalpinia Brasiliensis*) is not the least important. The West Indian locust-tree (*Hymenæa Courbaril*) affords a close-grained tough wood, which is found well adapted for the beams of steam-engines, while the Guiana purple-heart even excels it in toughness; and being found to resist well the shock of artillery discharges, it is sought after for mortar-beds.—§ III. *Mimoseæ*, petals valvate in estivation. The principal genera are *Acacia* and *Mimosa;* the latter genus chiefly remarkable on account of the irritability displayed by the leaves of *M. pudica* and *sensitiva*. Many species of *Acacia* yield gum-arabic and gum-senegal. The Australian species, called 'Wattles,' have astringent bark which is used in tanning; in these the leaf-stalk is often flattened into a phyllodium, or false-leaf; in the young plant there may be no compound leaves developed, but these ultimately appear at the tips of the phyllodia.

ROSACEÆ.—Like the preceding, this is one of the most extensive natural orders, comprehending nearly 1000 described species, which are herbs, shrubs, and trees, often of very dissimilar habits and appearance, but all bearing a striking resemblance in their fructification to the single or wild rose of our woods and hedges, which may be taken as the type of the order. Among the trees may be mentioned, as familiar examples, the almond

(*Amygdalus*), the pear and apple (*Pyrus*), the sloe and plum (*Prunus*), the peach and nectarine (*Persica*), the cherries and laurels (*Cerasus*); among the shrubs, the rose (*Rosa*), the hawthorn (*Cratægus*), the bramble and raspberry (*Rubus*), and the quince (*Cydonia*); among the herbs, the common yellow *Potentilla* of the roadsides, the *Geum*, the *Tormentilla* of our woods and commons, and the delicious strawberry (*Fragaria*). From the varied nature of its genera, the order is divided by some authors into seven sub-orders for the purposes of detailed description. All the different sections exhibit the following general characteristics: Leaves, alternate, generally compound, and always furnished with stipules; calyx, five-lobed, united below, but separate and expanding above; corolla, of five, or sometimes four petals. The ovary is one-celled, and there is seldom more than one seed, scarcely ever more than two in each cell. Carpels numerous, and generally inclosed in the fleshy tube of the calyx.

Rosaceous Flower.

The following are the sub-orders: 1. CHRYSOBALANEÆ, or cocoa-plum family, represented by *C. icaco*, a shrub found in the West Indies, where its fruit, which is about the size of a plum, of a whitish-yellow, and possessing a sweetish taste, is brought to the markets. There are about nine genera belonging to this tribe, all of which are trees or shrubs, with simple alternate stipulate leaves, and flowers in racemes or panicles. They are natives of the tropical countries, and differ from the almond tribe in having irregular petals and stamens, and in the style arising from the base of the ovary; the stipules are not united to the petiole.—2. AMYGDALEÆ, or almond family, represented by the common almond (*Amygdalus communis*), and embracing the peach, apricot, nectarine, plum, cherry, &c. well known for their delicious fruits, and a few bushes remarkable for their gay appearance during the flowering season. The fruits of this tribe are for the most part edible; and though the leaves and bark possess medicinal properties, yet one of the most subtile poisons—prussic acid—can be extracted both from the fruit and leaves of the almond.—3. ROSEÆ, or roses proper, the type of which is the single wild-roses of our hedges. The section is distinguished botanically by the numerous achenes inclosed in a fleshy calycine tube which is contracted at the orifice. They have all a corolla of five equal slightly indented petals, capable of being increased indefinitely by cultivation; numerous stamens; a five-cleft calyx. The pitcher-shaped portion of the calyx becomes the hip as the seeds ripen, and forms a false pericarp, inclosing the numerous bony carpels. Many of the plants have pinnate leaves and prickles on their stems. Most of them are fragrant, and the leaves of some, as the sweet-brier, are replete with a fragrant volatile oil, which appears to be secreted by glands dispersed all over the foliaceous surface of the plant.—4. POTENTILLIDÆ, embracing those plants which agree with the common *Potentilla* in the construction of their flowers—that is, in having a calyx of ten sepals; its tube short, or nearly flat, not inclosing the fruit; a corolla of five petals; and the stamens, which are numerous, forming a ring round an elevated or flat receptacle, on which are placed numerous carpels. By this test the student will find that the section comprises not only herbs, such as the potentilla, geum, tormentilla, and strawberry, but also erect and trailing shrubs, as the raspberry and bramble. These genera, though alike in their flowers and in many of their habits, are otherwise very dissimilar. In the potentilla, for example, the carpels form the prominent part of the so-called fruit, while in the strawberry the receptacle becomes fleshy and edible. Again, in the raspberry, the receptacle is a torus surrounded by the carpels, which swell out and soften, forming the edible portion. The leaves and stems of these genera are also very dissimilar, but the habit of increasing by suckers or runners is prevalent in all.—5. SANGUISORBIDÆ, a section of herbaceous perennials, illustrated by *Sanguisorba officinalis*, or the weed burnet of our pastures. This tribe is distinguished by having one or two achenes inclosed within the dry calyx-tube. The flowers often have no petals, but the clefts of the calyx are coloured, and the flowers are generally furnished with glossy coloured bracts.—6. SPIRÆIDÆ, deciduous shrubs and perennial herbs, represented by *Spiræa Ulmaria*, or meadow-sweet. In this section, the five-cleft calyx is lined with the dilated receptacle, which forms a sort of cup for the carpels, which are in the form of follicles. The beautiful hardy shrub named *Neillia thyrsiflora* belongs to this tribe, which contains a large number of shrubby ornamental *Spiræas*, as well as herbaceous kinds.—7. POMEÆ, an extensive and varied section, the type of which is the common apple (*Pyrus malus*). It comprehends the apple, pear (*Pyrus communis*), the mountain-ash (*P. aucuparia*), the white beam-tree (*P. Aria*), the quince (*Cydonia*), and the hawthorn (*Cratægus*). In all of these genera, which are trees and shrubs, the flowers are remarkably similar; but the habits of the plants, the leaves, and the fruit, present numerous differences.

The properties of the order have already been so far noticed in the preceding detail, that it may be stated of them generally as follows: The fruit of some of the *Chrysobalaneæ* is eaten under the name of the cocoa-plum. The *Amygdaleæ* include the almond, plum, cherry, and sloe; the leaves and kernels contain prussic acid, which, in a concentrated form, is one of the subtilest poisons; but being generally diluted in a natural state with gum, sugar, &c. it is harmless, and serves to give an agreeable flavour to the fruits containing it. The *Roseæ* are chiefly valued for their ornamental flowers, but they also yield valuable extracts—as attar of roses, rose-water, conserve of roses, &c. The fragrant essential oil called attar of roses is distilled chiefly from the common cabbage-rose (*Rosa centifolia*) and its varieties; 20,000 flowers of roses are required to make a rupee weight of the attar, which sells for £10. The general character of the *Sanguisorbidæ* is astringency. The roots of *Spiræa filipendula* and *Ulmaria*, as well as those of some other plants belonging to the *Spiræidæ*, have been used as a tonic. Of the *Potentillidæ*, the roots of several are astringent and febrifugal, and the fruits of such as the raspberry and strawberry are delicious and wholesome. The *Pomeæ*, under cultivation, supply wholesome

and delicious fruits, of which the apple, pear, quince, and service-berry are familiar examples.

MYRTACEÆ.—The order consists of upwards of 60 genera, and about 1300 known species. They are all trees or shrubs, with simple exstipulate leaves, which are for the most part opposite, full of transparent dots, and with an intra-marginal vein round the edge. The substance of the leaf is coriaceous, and the dots are glands, or cysts, full of a fragrant volatile oil. The inflorescence is both terminal and axillary, variable in its form, but generally aggregate—the flowers being regular and united, of a white, red, or sometimes yellow colour, but never blue. The tube of the calyx adheres to the ovary, and is from four to eight cleft, persistent or deciduous. The petals, which are rarely wanting, are equal in number to, and alternate with, the segments of the calyx; the stamens are inserted with the petals, and are twice as many, or (usually) indefinite, and then arranged in several

Pomegranate.

series; the anthers are two-celled, and burst longitudinally. Fruit, baccate or capsular; style and stigma, simple; many-celled, or one-celled by the obliteration of the dissepiments of the carpels. Seeds, generally indefinite, seldom few, and without albumen.

Among the edible fruits belonging to the order may be mentioned the delicious guava, yielded by several species of *Psidium;* the rose-apple and jamrosade, produced by *Eugenia* and *Jambosa.* Of spices yielded by the order, which are all more or less aromatic, we have the clove, which is the unexpanded flower-bud of the *Caryophyllus aromaticus;* all-spice, Pimento or Jamaica pepper, the dried berries of *Eugenia pimento;* and also the dried berries of the common myrtle. It is the volatile oil found in the dots of the leaves, the unexpanded petals, and in almost all the parts of the plant, that gives to them their fine aromatic fragrance. The pomegranate (*Punica granatum*) forms a delicious fruit in warm countries; the pericarp or rind is used in the East as an astringent; and the bark of the root is esteemed an efficient anthelmintic.

Some species of the beautiful genus *Metrosideros* yield hard and heavy timber, which the South Sea islanders prize for their clubs and other weapons of war. The gum-trees of Australia (*Eucalypti*) deserve special notice as among the most valuable economical plants of our Australian colonies. They are distinguished by a remarkable operculate calyx, and their bark separates in layers, giving rise to the statement that the trees of Australia shed their bark instead of their leaves in winter. Their leaves often stand in a vertical position, and are remarkably hard and coriaceous. These trees grow to an enormous size, and yield very durable timber. They supply the place of the European oaks as a source of tannin. *E. resinifera* yields, on incision, an astringent matter, called Botany Bay kino; while several others yield saccharine matter. A peculiar red gum is contained in cavities of the wood of *E. robusta.* The leaves of some species of *Leptospermum* are used in Australia as a substitute for tea.

CUCURBITACEÆ.—This is a large and interesting family of herbaceous plants, containing 56 known genera, and about 300 species. The roots are annual or perennial, fibrous or tuberous; the stems succulent, climbing by means of lateral tendrils formed of the abortive stipules, and furnished with large alternate, palmated rough leaves. The flowers are usually unisexual.

The Cucurbits are natives of all hot climates, but are most abundant in India and South America; a few exist in the northern parts of Europe, and some are found at the Cape of Good Hope. In an economical point of view, the order is of considerable importance, furnishing the well-known esculents—the cucumber, melon, gourd, pumpkin, and calabash; and the purgatives colocynth and elaterium. The general properties of the gourd family may be regarded as bitter and purgative—these qualities pervading more or less all the species, and rendering their fruit either esculent or purgative. The seeds of all are sweet and oily, and from some a considerable quantity of fine-flavoured oil may be expressed. The roots and leaves are sometimes replete with a bitter drastic juice. The fruit of many of the members grows to an enormous size; the calabash, for example, being sometimes found six feet long and eighteen inches in circumference. *Gherkins* are the fruit of the common cucumber, pickled when in a young state. The fruit of *Lagenaria vulgaris* is in common use for water-bottles in the Greek islands and generally in the East. It has probably given rise to the clay water-bottles in form of a round bulb ending in a long neck, which much resemble it in shape, and to which the bottles in use all over the world may be traced as modifications. Many of the ornaments of ancient Egyptian architecture are traceable in a similar manner to vegetable forms peculiar to the region.

CACTACEÆ.—The Indian figs, or Cacti, constitute one of the most singular and interesting orders in the vegetable kingdom. They are unique in their forms and habits, having perennial succulent, angular, or rounded spiny stems. In general, the stems and branches are jointed; the leaves are either very minute, or altogether wanting, their place being supplied by strong spines. They are all natives of tropical America, but thrive well in all hot, dry, and exposed places. Of the more common genera, we may mention the following: *Mammillaria*, so called from the pap-like tubercles which cover its sub-cylindrical stem. Each tubercle is crowned with a little tuft of radiating spines; and the flowers, which are sessile, are ranged in a kind of zone round the plant. The melon cactus (*Melocactus communis*), which has a more or less globose stem, with alternate furrows and ridges,

the latter being armed with tufts of spines; the stem is crowned by a woolly tuft, from which spring the flowers. The hedgehog-thistle (*Echinocactus*) has also a globose stem, but wants the woolly head, and has its flowers springing from the tufts of spines which arm the ridges. Some of the species grow to an enormous size. A plant of *E. platyceras*, growing at Kew, measured 9 feet in height, 9½ in circumference, and weighed upwards of a ton. The torch-thistle (*Cereus*) has the stem angular, the projecting angles being armed with spiny tufts, from which the flowers generally spring. The old-man cactus (*Polocereus senilis*) is so called from its resemblance to an old man's head, being covered with long white hairs. The Peruvian torch-thistles (*Cereus peruvianus* and *hexagonus*) are still more gigantic plants, often attaining a height of forty feet, though their stems be not thicker than a man's arm. The rat's tail cereus (*C. flagelliformis*) is well known from its long whip-like stems, which hang down from the sides of the suspended pots in which it is usually grown. The night-flowering cereus (*C. grandiflorus*), so called from its blossoms opening during night, and fading before morning, has an angular, branched, and climbing stem, throwing out roots at every point. The genus *Rhipsalis* has slender jointed stems, which look like samphire; and the opuntias, which are numerous and useful, are distinguished by their round, flat, leaf-like bodies, united together by joints, and for the most part covered with spines.

The fruit of many of the Cactaceæ is esculent, but is rather insipid, having little of that acidulous flavour which characterises the Currantworts, to which the family is allied. It is upon the *Opuntia cocchinellifera*, the Nopal plant, that the cochineal insect, so valuable in the arts, chiefly feeds. In the south of Europe, the prickly pear (*O. communis*) is reared as a hedge, and also for its fruit, which is edible, and yields a rich carmine pigment; and the Indian fig (*O. tuna*) is grown for similar purposes in Brazil.

GROSSULARIACEÆ.—This is a well-known order, consisting principally of one genus, *Ribes*, which includes all the gooseberries and currants of our gardens. The species, of which there are upwards of eighty, are unarmed or thorny shrubs, with round or irregularly angled stems and branches; simple, lobed, alternate leaves, destitute of stipules and tendrils. The inflorescence is axillary and in racemes. The calyx, which is often coloured, is four or five cleft; petals, perigynous, equal in number to, and alternate with, the segments of the calyx; stamens, of the same number, alternate, and inserted with the petals; filaments, distinct; anthers, two-celled, bursting longitudinally; ovary, one-celled, cohering with the tube of the calyx; ovules, indefinite; fruit, a berry, crowned with the remains of the flower, one-celled, filled with pulp with two parietal placentas; seeds, numerous, suspended among the pulp by filiform funicles; testa, externally gelatinous; albumen, horny.

The order is very conveniently grouped into two sections—namely, the Gooseberries, which have prickly stems, and the flowers either singly, or in clusters of not more than two or three; and the Currants, which are entirely without spines, and the flowers in racemes. There are a few species, such as *Ribes dracantha* and *saxatile*, which may be considered as intermediate, these having the spines and habit of growth of the one, and the racemose inflorescence of the other. The common gooseberry (*R. Grossularia*), the red currant (*R. rubrum*), the black currant (*R. nigrum*), and the flowering currant (*R. sanguineum*), are familiar examples of the order, and all too well known to require any detailed description. The gooseberry is found wild in many parts of Britain; and is reared in the north of England to greater perfection than in any other country.

Gooseberries and currants have agreeable acid fruits, the acidity or sweetness depending upon the relative quantities of malic acid and sugar which they contain. The blackberry has tonic and astringent properties, infusions of the leaves being used for this purpose.

SAXIFRAGACEÆ.—This order consists chiefly of very small herbaceous plants, with alternate or opposite leaves, and is readily distinguished by the peculiar ovary, which is more or less completely inferior, consisting of two carpels which diverge at the apex. As useful plants, they are unimportant, but they are the most charming that greet the eye of the botanist in his mountain rambles. *Saxifraga stellaris* and *S. aizoides* are the great ornaments of Highland streams at a low elevation; while higher up, the rocky banks are covered with a purple carpet of *S. oppositifolia*, or the rarer *S. rivularis*, which attracts many a botanist to the summit of Loch-na-gar. *S. cernua* is confined to the summit of Ben Lawers. But it is not alone the Scottish mountains that are adorned with these 'alpine gems;' *S. Boussingaultii* reaches to nearly 16,000 feet on Chimborazo.

UMBELLIFERÆ.—This is one of the most extensive and important of the natural orders, comprising about 300 genera, and above 1500 species.

Common Hemlock:
c, flower; *d*, seed.

The genera, though presenting many minor differences, are, on the whole, well marked; so that no one who has seen the flower of the parsley and common hemlock can have any difficulty in detecting an umbelliferous plant. The species are for the most part herbs, seldom shrubs, with fistular furrowed stems, loving damp waste places, and varying much in their properties, according to the climate under which they are grown. The leaves are generally divided, sometimes simple; are alternate, and clasp the stem by a broad sheathing petiole. The flowers are white, pink,

yellow, and blue, and in umbels, which are simple or compound, and these are with or without bracts at their base: when seated at the base of the umbel, the bract is called an involucre; when at the base of the umbellules in the compound head, an involucel. The calyx is superior and five-toothed; petals, five, and inserted on the outside of a fleshy disc, which is placed on the top of the ovary; stamens, five, and inserted alternately with the petals; ovary, inferior, and two-celled, with pendulous ovules; styles, two, distinct; stigmas, simple. The fruit (cremocarp) consists of two carpels, united by a common axis, from which they separate when ripe; the external part of the carpels is traversed by linear ridges, which are divided into primary and secondary, there being five of the latter, and four of the former, between them. The ridges are separated by channels, below which are often placed, in the covering of the seed, receptacles or vittæ of an oily matter. The seed is pendulous, usually cohering with the carpel, rarely loose.

Among the more familiar genera may be mentioned the parsnip (*Pastinaca*), the cow-parsnip (*Heracleum*), the celery (*Apium*), the carrot (*Daucus*), the hemlock (*Conium*), the cow-bane (*Cicuta*), and the coriander (*Coriandrum*).

The properties of the order are very various. Some of the plants are harmless and esculent, while others are narcotic poisons; a third set are antispasmodic, owing to the presence of a gum-resin containing a fetid sulphur oil; while a fourth set are carminative, from containing a volatile oil. 1. Among the harmless plants used as esculents may be mentioned the chervil, celery, arracacha, earth-nut, pig-nut, samphire, carrot, fennel, parsnip, parsley, and skirret. 2. Poisonous plants containing acrid and narcotic principles: fool's parsley, water hemlock or cow-bane, spotted hemlock, and hemlock-dropwort or dead-tongue. The last-named plant has been found to be poisonous only in certain localities. 3. Gum-resinous species, usually with a fetid odour: *Narthex assafœtida*, a native of Persia, yields the true assafœtida; *Ferula orientalis* furnishes a fetid resin in Morocco; *Galbanum officinale* and *Opoidia galbanifera* yield galbanum; *Dorema ammoniacum* yields the Persian gum ammoniac; *Opoponax chironum* produces the gum-resin called opoponax. 4. Aromatic and carminative plants, containing volatile oil: caraway, dill, coriander, cummin, carrot, anise, &c.

CAPRIFOLIACEÆ.—A well-known order, consisting of 12 or 14 genera, and about 220 species. They are erect or twining shrubs, rarely trees, having opposite, simple, or pinnate leaves, without stipules; and flowers terminal in corymbs, or axillary. The flowers are white, scarlet, or yellow, and often sweet-scented, as in the common honeysuckle. The order has been divided into two sections—namely, the SAMBUCEÆ, or elder tribe, and the LONICERÆ, or true honeysuckle tribe.

RUBIACEÆ.—This is a large, and in many respects not a well-defined order, composed of small trees, shrubs, and herbs. It has been divided into two orders by some authors: CINCHONACEÆ, containing those plants most resembling cinchona; and GALIACEÆ, or STELLATÆ, those most resembling the galiums or bedstraws. The *Cinchonaceæ* and *Galiaceæ*, indeed, form two well-marked groups of plants, abundantly distinct from each other in habit and in geographical distribution: the one consisting of trees, shrubs, and herbs, with simple opposite leaves and interpetiolar glandular stipules; almost exclusively inhabiting the hotter parts of the world, most of them eminently conspicuous for their economical products and the beauty of their broad foliage and flowers; the other composed entirely of straggling herbaceous plants, with weak angular stems and narrow verticillate exstipulate leaves, inhabiting northern countries, and, with one or two exceptions, alike inconspicuous for use and ornament. Unfortunately, however, fructification does not supply any character whereby those two ideally distinct groups of plants can be clearly separated from each other, and in the limitation of natural orders something more than a difference of habit is considered requisite. The recent discovery of the peculiar axillary glands of *Cinchonaceæ* in *Galiaceæ* serves still further to break up the supposed distinctions between these groups. De Candolle has proposed a further subdivision into thirteen sub-tribes.

By far the greater number of the species are tropical plants, though many are amongst the most common and neglected of British weeds. Madder (*Rubia tinctorum*) is common in gardens, and is much cultivated in Belgium and Holland for its roots, which yield a rich brownish-red dye, called Turkey red. The *Galiums* or bedstraws are familiar plants, growing on hedges, on dry banks, or sides of old ditches, and known by the common name of cleavers, ladies' bedstraw, crosswort, and the like. *Asperula odorata*, another of the order, is the well-known woodruff, which acquires, when dried, a most delicate fragrance. The coffee-tree (*Coffea*), Jesuit's bark (*Cinchona*), the Cape jasmine (*Gardenia*), and ipecacuanha (*Cephäelis*), are also well-known members.

The properties of the order are very varied. The roots of many, as the madders and bedstraws, contain a large quantity of colouring matter; and it is said that fowls fed upon the roots of some plants of this order have their bones dyed of a red colour; in other cases, the plants are acrid, emetic, purgative, or diuretic. The bark (as that of the Cinchona, or Peruvian bark) is sometimes bitter, tonic, and astringent. The ipecacuanha plant (*Cephäelis ipecacuanha*) of South America, the annulated root of which is so valuable in medicine, and by which it is easily propagated, has been lately (1871) introduced into India by the government, for the purpose of cultivation. Many of the plants were grown and sent out from the Royal Botanic Garden of Edinburgh. Quinine, now so extensively used in medicine, is obtained from different species of cinchona, but chiefly from the bark and young shoots of *C. Calisaya.* The cultivation of cinchona is now being successfully carried on in India, and it has been lately introduced, with that object, into Java and Australia. The value of the roasted albumen of the coffee-berry is too well known to require allusion; and the fruits of others of the order have been recommended as answering the same purpose.

COMPOSITÆ.—This is one of the most extensive of the natural orders, containing not fewer than 900 genera, and between 9000 and 10,000 species. The members are herbaceous plants or shrubs, with leaves alternate or opposite, without stipules, and usually simple. What is called the flower is an aggregation of unisexual or hermaphrodite *florets*, collected in dense heads upon a common

receptacle, surrounded by an involucre, as exemplified in the common daisy and dandelion. As the compound leaf is composed of a number of leaflets, so is the composite flower made up of a number of florets arranged on one receptacle, which is furnished with a calyx-like involucre. Each floret is complete in itself, having all the appendages of bracts, calyx, corolla, stamens, and pistil, although the calyx is in a much reduced state, appearing in the form of bristly hairs. The corolla is monopetalous, and either ligulate, tubular, or bilabiate—that is, has two equal lips cut into several lobes. The stamens are equal in number to the teeth of the corolla, and alternate with them ; the anthers grow together, so as to form a kind of cylinder, through which passes the style, ending in a two-lobed stigma. The ovary is inferior, one-celled, with a single erect ovule. The fruit is an achene, which retains the pappus when ripe, and falls without opening ; the appearance of this pappus or down is familiarly illustrated in the head of the ripe dandelion.

The order has been divided into three sections : 1. *Cichoraceæ*, in which all the florets are ligulate and perfect. 2. *Corymbiferæ*, most of the florets tubular, all hermaphrodite, or those of the circumference filiform or tubular, and pistiliferous or ligulate ; style, not jointed. 3. *Cynarocephalæ*, all the florets tubular ; style, jointed. The Composite plants are widely scattered over the globe, forming, according to some authorities, one-twelfth of its vegetable productions. Humboldt states that they constitute one-seventh of the flowering-plants of France, one-eighth of those of Germany, one-fifteenth of those of Lapland, a sixteenth of those of New Holland, a sixth of the North American Flora, and one-half of that of America within the tropics. The Composites are herbaceous in the colder quarters of the globe, and become shrubby as we approach the equator.

The Cichoraceæ are well illustrated by the common lettuce (*Lactuca*), the dandelion (*Taraxacum*), the succory (*Cichorium*), and the sow-thistle (*Sonchus*), which are common British plants. All the members of this section yield a milky juice, which is bitter, astringent, and slightly narcotic. Many of them are used in medicine—as the lettuce, from which the narcotic and diuretic *Lactucarium* is obtained. Many are also used as articles of food ; thus, endive (*Cichorium Endivia*) is employed as a salad ; so is the garden lettuce when young, the root of the sonchus, and perhaps, more than all, the root of *C. Intybus*, or wild succory, which is roasted and largely mingled with coffee under the name of chicory. The Corymbiferæ, which have the central florets tubular, and the outer ones generally ligulate, are illustrated by the daisy (*Bellis perennis*), the chamomile (fig.) (*Anthemis nobilis*), the groundsel (*Senecio*), the tansy (*Tanacetum vulgare*), dahlia, marigold, &c. The juice of this section is watery; sometimes bitter and tonic, and sometimes acrid. Many of them contain volatile oils, which are used for various purposes, and some yield yellow and other dyes. Among the most useful of the section may be mentioned the Jerusalem artichoke, wormwood, chamomile, tansy, and arnica—the last much employed in homœopathic practice ; indeed, most of the Corymbiferæ are of medicinal value. *Cynarocephalæ*.—The plants of this division are bitter and tonic. By cultivation, this bitterness is lessened, and they become edible. The section may be illustrated by the cardoon and common artichoke,

Chamomile.

all the thistles (*Carduus*), the burdock (*Arctium*), the bluebottles (*Centaurea*), the safflower (*Carthamus*). The properties of the artichoke are well known, as are also those of the carthamus, which is used in dyeing as well as in medicine. The thistle is chiefly interesting as being emblematical of Scotland ; but neither antiquaries nor botanists have been able to discover with certainty the species entitled to the appellation of *the* Scotch thistle. *Onopordum Acanthium* adorns the grave of Burns in Dumfries, and is usually employed in national demonstrations ; but Burns had another species in view as the 'bur-thistle'—namely, *Carduus lanceolatus*. Others prefer the milk-thistle ; and so far as the figures on the coins of the Scotch kings indicate a special species, the milk-thistle appears to be the one indicated.

§ COROLLIFLORÆ.

In this section the flowers are dichlamydeous, the petals united into a tube, hypogynous, stamens inserted in the corolla (or in the first four orders arising directly from the receptacle). The plants may usually be recognised by the corolla appearing to consist of one piece, the petals being united (gamopetalous). Many of the orders have regular flowers, but a large number have them two-lipped, and therefore irregular, such as the Foxglove, labiate plants, and Acanthi.

The following are the orders contained in this section :

*Ericaceæ—Heathworts.
*Pyrolaceæ—Winter-greens.
*Montropaceæ—Fir-rapes.
Epacridaceæ—Epacrids.
Ebenaceæ—Ebony order.
*Aquifoliaceæ—Holly order.
Sapotaceæ—Sapotads.
Myrsinaceæ—Myrsine order.
Jasminaceæ—Jasmines.
*Oleaceæ—Olives.
Salvadoraceæ—Salvadora order.
Asclepiadaceæ—Asclepiads.
*Apocynaceæ—Dogbanes.
Loganiaceæ—Strychnads.
*Gentianaceæ—Gentian worts.
Bignoniaceæ—Trumpet-flowers.
Gesneraceæ—Gesnerads.
Crescentiaceæ—Calabashes.
Pedaliaceæ—Pedalium order.
*Polemoniaceæ—Phlox order.
Hydrophyllaceæ—Water-leaves.
Diapensiaceæ—Diapensia order.
*Convolvulaceæ—Bindweeds.
*Cuscutaceæ—Dodders.
Cordiaceæ—Sebestens.
*Boraginaceæ—Borageworts.
Ehretiaceæ—Ehretia order.
Nolanaceæ—Nolana order.
*Solanaceæ—Potato order.
*Atropaceæ—Nightshades.
*Orobanchaceæ—Broom-rapes.
*Scrophulariaceæ—Figworts.
*Labiatæ or Lamiaceæ—Dead-nettles.
*Verbenaceæ—Verbenas.
Stilbaceæ—Stilbids.
Selaginaceæ or Globulariaceæ—Selagids.
Acanthaceæ—Acanthads.
*Lentibulariaceæ—Butterworts.
*Primulaceæ—Primroses.
*Plumbaginaceæ—Leadworts.
*Plantaginaceæ—Ribworts.

ERICACEÆ.—This is an extensive order of shrubs or under-shrubs, with leaves evergreen, rigid, entire, whorled, or opposite, and without stipules. 'The name of the heath family,' as it has been very appropriately remarked, 'conjures up immediately the image of a number of narrow-leaved plants, with globular, ventricose, or bell-shaped flowers; and we are apt at first to think that the family is so natural a one as to require very little explanation.' Did the order include only the heaths, this would be the case; for all the heaths, differing as they do in some particulars, may be recognised at a glance; but as the order includes the Rhododendrons, the Azaleas, and Kalmias, besides several other plants which have not so strong a family likeness to each other as the heaths, it becomes necessary to point out the botanical resemblances which connect them together. The first and most striking of these is the shape of the anthers—each of which appears like two anthers stuck together—and the manner of their opening, which is always by a pore or round hole in the upper extremity of each cell. The filaments also in all the genera grow from beneath the seed-vessel, being generally slightly attached to the base of the corolla. There is always a single style with an undivided stigma, though the capsule has generally four cells, each containing several small seeds. The calyx is four or five cleft, and the corolla is tubular, with a larger or smaller limb, which is also four or five cleft. The above are the connecting points between the various genera which compose the family; but the differences are such as to require a subdivision of the Ericaceæ into the following sub-orders: 1. *Ericeæ*, or those most closely resembling the true heaths, their fruit being loculicidal, rarely septicidal or berried, and the buds naked; 2. *Rhododendreæ*, those allied to the Rhododendrons, their fruits being capsular septicidal; the buds, scaly, resembling cones; 3. *Pyroleæ*, those allied to the winter-green of our woods, and distinguished by having a minute embryo at the base of fleshy albumen, the two preceding having a cylindrical embryo in the axis of the albumen. 1. *Ericeæ.*—This sub-order may be arranged into two sections—namely, the true heaths (*Ericidæ*), having bracteal pedicels of flowers, the corolla of each flower being more or less bell-shaped or globose, with a four-cleft limb, a four-lobed calyx, and eight stamens; and the *Andromedidæ*, which have the corolla more globose, the limb five-cleft, the calyx five-lobed, and ten stamens. In other respects both sections are nearly alike; both have a honey-bearing disc, and both have the leaves, which are narrow and leathery, slightly rolled in at the margin. The stamens appear differently in the several genera; some being capitate, others ending in awn-shaped horns; in some they are concealed by the corolla, in others they are exposed. The style, in some of the genera, projects considerably beyond the corolla, in others it is rather contracted. The more familiar genera are, the common heath of our moors (*Erica tetralix*), common ling or heather (*Calluna vulgaris*), and the Cape heaths, many of which have glutinous, cylindrical corollas. The genera *Andromeda*, *Zenobia*, the strawberry-tree (*Arbutus*), the bearberry of our Highlands (*Arctostaphylos uva-ursi*), and *Gaultheria*, frequent in gardens, are illustrations of the second section. Plants belonging to this sub-order cover large tracts of our own country, are common in North and South America, and abound at the Cape of Good Hope, which has supplied our gardens with hundreds of the most beautiful species of *Erica*. All of them possess bitter, astringent, and diuretic properties; and the berries of some, as well as the flowers, have been used in dyeing. The Arbutus is a very ornamental shrub, the berries of which are edible, and may be used in the preparation of a wine. 2. *Rhododendreæ.*—The plants in this sub-order have all less or more a resemblance to the well-known genus *Rhododendron*, the species of which have generally evergreen leaves, and large showy flowers produced in terminal corymbs. The calyx is small; the corolla, large in proportion, bell-shaped, and deeply five-cleft; the stamens, five or ten; the capsule, five-celled and five-valved. The flowers are generally purple or whitish, though in some they are yellow, pink, or bright scarlet, as in the Nepaul tree-rhododendron (*R. arboreum*). The genus *Azalea* is very nearly allied to the rhododendron; but its species—the Indian and American—differ considerably in their inflorescence and leaves; the latter in some species being deciduous. *Kalmia* and *Menziesia* are familiar garden genera; *Ledum palustre*, or wild rosemary, and the Labrador tea-plant (*L. latifolium*), also rank under this section, whose members have an extensive range, being found abundantly in Europe, Asia, and North America. They are chiefly inhabitants of high cold regions, and in this particular agree with the general habit of the order. The Rhododendreæ possess soporific properties—*R. crysanthum* being used in gout and acute rheumatism. The Azaleas are astringent, and some yield a poisonous honey, well distinguishing these plants from the true heaths, none of which are poisonous. The honey which gave rise to symptoms of poisoning in the Greek soldiers during the celebrated Retreat of the Ten Thousand mentioned by Xenophon, was obtained from *Rhododendron ponticum* and *Azalea pontica*, two ornamental shrubs much cultivated in our gardens and shrubberies. It has been observed that the leaves and flowers of *R. arboreum* poisoned the cattle which partook of them in Kumaon; and the leaves of *R. ponticum* have poisoned sheep and goats in this country. Some species yield a resinous matter having a powerful and oppressive odour. *R. setosum* is the *Tsalu* of the Sikkim Bhoteas and Tibetans, who attribute the oppression and headaches attending the crossing of the loftiest passes of the Eastern Himalaya to the strongly resinous odour of this and *R. anthopogon*, the *Palu* of the natives. The Rhododendrons introduced by Dr Hooker from Sikkim form the most valuable addition to our ornamental plants that has been made for many years. *R. nivale* occurs at elevations of from 16,000 to 18,000 feet on the Tibetan frontier. For eight months of the year, it is buried under many feet of snow; for the remaining four it is frequently snowed and sunned in the same hour. *R. ferrugineum* and *hirsutum* are the roses of the Alps, and form a shrubby belt on the Swiss mountains. 3. *Pyroleæ.*—This sub-order is well illustrated by the winter-green (*Pyrola*), which is common in British woods. The species of Pyrola are evergreen plants, with white flowers, the corollas consisting of five distinct

petals, and which have ten stamens, with anthers opening by a pore: the style is single, ending in a capitate stigma cut into five lobes; the fruit, a five-celled capsule.

OLEACEÆ.—Under this order are reckoned upwards of 20 genera, and about 130 species. They are trees and shrubs with erect or climbing stems, and with leaves opposite, petiolate, simple, seldom ternate or pinnate, and destitute of stipules. The inflorescence is often paniculate; the flowers regular, and sometimes, by abortion, polygamous; calyx, free, divided, and persistent; corolla, hypogynous, four-cleft, and rarely wanting; stamens, two, alternating with the lateral lobes of the corolla when present, or when there are four petals connecting the lateral petals in pairs; filaments, free; anthers, two-celled, bursting longitudinally; ovary, free, two-celled; ovules, pendulous and in pairs; style, sometimes wanting; stigma, entire or bifid; fruit, fleshy or dry, sometimes one-celled by abortion. According to the character of the fruit, the order is sometimes subdivided into the OLEÆ, having it a drupe or berry, and the FRAXINEÆ, having it samaroid.

The principal genera are—*Olea*, the olive; *Fraxinus*, the ash; *Ornus*, the manna-ash; *Ligustrum*, the privet; *Syringa*, the lilac; *Chionanthus*, the fringe-tree; and *Phillyrea*. The olive (*O. Europæa*) is a well-known tree, with small white flowers, and a fleshy drupe like a sloe, from which is expressed the olive oil of commerce. The ash (*F. excelsior*) is a common British tree, with pinnate leaves, the flowers without a corolla, and the fruit a winged samara or key, with one or two seeds. The manna-ash (*Ornus Europæa*), though closely resembling the common ash in its leaves and samara, has loose panicles of white flowers, the corollas of which are divided into four long narrow segments. The privet (*Ligustrum vulgare*), the lilac (*Syringa vulgaris*), and Phillyrea, are too common ornamental shrubs to require particular notice.

Economically, the oliveworts are of great importance. Besides the oil of the olive, so universally used in Europe, the unripe berries are pickled and eaten on the continent to provoke an appetite; and the bark, which is bitter and astringent, is used as a substitute for cinchona. The bark of the common ash, as well as that of several others, is astringent and febrifugal, while the wood of the former is easily worked, and exceedingly tough and durable. What is in the present day called manna is a saccharine cathartic, procured by wounding the bark of *Ornus rotundifolia* and *Europæa*. The sweetness of this substance is not due to the presence of sugar, but to a distinct principle called Mannite, which differs from cane-sugar in not fermenting with water and yeast.

LOGANIACEÆ.—This order consists chiefly of woody plants, with opposite entire, stipulate leaves, natives of the tropics. It is chiefly remarkable from containing *Strychnos Nux-vomica*, the plant from which strychnine is prepared. It is called rat's-bane, poison-nut, or koochla. This tree abounds on the Malabar and Coromandel coasts of the Indian peninsula, and produces a small orange-like fruit full of pulp, in which the seeds are imbedded. The latter alone form the fatal drug; but the wood of the tree is intensely bitter, and is employed in the cure of intermittent fevers and the bites of venomous snakes. Strychnia, the alkaloid upon which the poisonous properties of the seeds depend, is an intensely bitter substance—so bitter, it is said, that its taste can be detected when dissolved in 600,000 times its weight in water. This has led to its use in the adulteration of malt liquors, and there is reason to believe that it is still used for this purpose. *S. toxifera* is the basis of the famous woorali employed by the Red Indians to poison their arrows, which thus cause immediate death when introduced into the slightest wound. *S. Tieuté* yields the upas radja of Java, not that half-mythical upas around which so many fearful fables have been entwined.

CONVOLVULACEÆ.—A well-defined order, containing about 670 species. The members are lactescent herbaceous plants or shrubs, with stems usually twining, and with leaves alternate, undivided or lobed, and exstipulate. The inflorescence is axillary or terminal; peduncles one or many flowered, the partial ones generally with two bracts; calyx, persistent in five divisions, and imbricated as if in more whorls than one—often very unequal; corolla, monopetalous, hypogynous, regular, deciduous; the limb, five-lobed and plaited; stamens, five, inserted into the base of the corolla, and alternate with its segments; ovary, free, with two or four cells; the ovules, definite and erect; style, one, usually divided at the top; stigmas, obtuse or acute; capsule, with the valves fitting at their edges to the angles of a loose dissepiment, bearing the seeds at its base; seeds, large; albumen, mucilaginous.

The more familiar genera are *Convolvulus* and *Ipomœa*, which have the corolla marked with a decided fold or plait, peculiarly imbricated calyx, and are climbing plants, not easily confounded with any other family. The *Convolvulus arvensis* is the wild climber of our hedges; and *C. tricolor*, so common in gardens, is a native of Sicily. The bindweed (*Convolvulus sepium*) is another of our hedge-natives, and is a well-known pest of the farm and garden. The roots of the order abound in an acrid, purgative, milky juice, exemplified in *jalap*—which is obtained from *Exogonium Purga*—and in *scammony*, the concrete juice of the root of *Convolvulus Scammonia*, the roots or tubers of *C. Batatas*, the sweet potato, are edible, as are also those of *Ipomœa macrorhiza*, whose insipid farinaceous tubers are found in the sandy soil of Georgia and Carolina, weighing as much as forty or fifty pounds.

BORAGINACEÆ.—The plants of this order are chiefly herbaceous, have round stems, alternate rough leaves, and flowers in scorpioidal cymes. Corolla, usually regular and five-cleft, imbricate, often with faucial scales. Fruit, two or four distinct achenes; seeds, exalbuminous. Some of the plants of the order yield dyes, such as the alkanet, others form pot-herbs; one maritime species (*Mertensia maritima*) is a vegetable substitute for oysters, having a similar flavour; and another (*Symphytum asperrimum*) is particularly recommended by agricultural writers as a suitable food for pigs. More sentimental associations surround the forget-me-not (*Myosotis palustris*), which is not uncommon in marshy situations in Britain.

NOLANACEÆ, SOLANACEÆ, ATROPACEÆ.—These three groups are sometimes associated under one order; and although tabulated separately, we shall save space by discussing their characteristics together, for they have many points

of structure in common. They are herbaceous plants or shrubs, with alternate leaves, and with angular or rounded stems; calyx, five (rarely four) parted and persistent; corolla, with the limb having the same number of lobes as the calyx, somewhat unequal, and deciduous; estivation, folded or imbricate; stamens, alternating with the segments of the corolla, sometimes one abortive; anthers, bursting longitudinally, or by terminal pores; ovary, two or more celled, rarely one-celled; ovules, usually indefinite; style, continuous; stigma, obtuse, very rarely lobed; fruit, either a capsule opening variously, a berry with the placenta adhering to the dissepiment, or a nuculanium, with five spurious-celled nucules, which have one seed in each; seeds, sessile.

The *Solanaceæ* closely resemble each other in their flowers, and also in their berry-like fruit, which is always crowned by the persistent calyx; seeds, albuminous; embryo, curved. The estivation is valvate or induplicato-valvate. The genus *Solanum*, to which belongs the bitter-sweet (*S. Dulcamara*), the garden nightshade (*S. nigrum*), and the potato (*S. tuberosum*), has the anthers opening by pores like the heaths; whereas all the other members have a slit down each cell, as the tomato, or love-apple (*Lycopersicum esculentum*), with its edible fruit; the capsicum (*C. frutescens*, &c.), whose dry inflated berry yields the cayenne-pepper of commerce; and the winter-cherry (*Physalis Alkekengi*), also with edible berry-like fruit. To the *Atropaceæ* belong the deadly nightshade or dwale (*Atropa Belladona*), which furnishes the deadly poison of that name; and the Barbary or box-thorn (*Lycium barbarum*). They are dangerous in their qualities, the leaves and flowers being narcotic and poisonous. They are distinguished from the preceding principally by the more or less imbricated estivation of the corolla; it is never valvate. The flowers are also more funnel-shaped, with a longish tube and spreading limb. The principal genera are—*Nicotiana*, *N. Tabacum*, being the Virginian tobacco of commerce, and *N. persica* is the source of Shiraz or Persian tobacco, so much esteemed by smokers. *Petunia*, which furnishes some of our best known garden favourites; *Nierembergia*, a genus of ornamental green-house plants; *Hyoscyamus*, the poisonous henbane; *Datura*, *D. Stramonium*, being the common thorn-apple; and *Brugmansia* and *Salpiglossis*, all more or less prized for their showy funnel-shaped flowers, some of which are highly fragrant. The plants of this order display marked narcotic properties, and cause dilatation of the pupil. *Nolanaceæ*.—'This tribe,' says Loudon, 'is principally known by the genus *Nolana*, the species of which are annual plants, natives of Chili and Peru, which have of late been much cultivated in British gardens. The flowers of *N. atriplicifolia*, one of the commonest kind, very much resemble those of the *Convolvulus tricolor*, and the leaves are large and juicy like those of the spinach. On opening the corolla there will be found five stamens, surrounding four or five ovaries, which are crowded together on a fleshy ring-like disc. These ovaries, when ripe, become as many drupes, enclosing each a three or four celled nut, which is marked with three or more grooves on the outside, and has three or more little holes beneath. All the species of Nolana have the same peculiarities in their seed-vessels, though they differ in many other respects.'

SCROPHULARIACEÆ.—The Figworts, of which the common foxglove may be taken as the type, form rather an extensive order, consisting of about 170 genera, and 1800 species. The plants are herbaceous, rarely shrubby, with round or square stems; the leaves being simple and exstipulate, opposite or whorled, seldom alternate, and either sessile or with footstalks. The inflorescence is very variable, being axillary or united, usually in spikes, racemes, or in panicles; calyx, inferior, persistent, and often unequal; corolla, tubular or inflated, with a short limb, which is flat or erect, nearly equally divided, or labiate; stamens, definite, two or four (didynamous), rarely five, filaments, free; anthers, two-celled; ovary, two-celled; style, simple; stigma, obtuse, rarely bifid; fruit, a dry capsule, rarely baccate.


Foxglove.

The following genera may be mentioned as illustrative of the order: *Scrophularia*, weeds common in Britain. *Digitalis*, the foxglove of our waysides and gardens; *Antirrhinum*, the well-known snapdragon; *Linaria*, the toad-flax of our hedges and banks; *Euphrasia*, the eyebright; *Veronica*, including the brooklime and the speedwells; *Rhinanthus*, the yellow rattle, *Verbascum*, the mullein; and *Calceolaria*, *Buddlea*, *Mimulus*, and others, now favourites in every flower-garden. The form of the flowers in the different genera varies considerably, as may be seen by examining the foxglove, the speedwell, and calceolaria—plants at the command of every one. The stamens also present considerable differences: in the foxglove (*Digitalis purpurea*) there are two long and two short; in *Pentstemon* there are five, the fifth being long and slender, and without an anther; in *Calceolaria* and *Veronica* there are only two. Various attempts have been made to subdivide the order—as, for example, into two sections, the one including the genera having four anther-bearing stamens, and the other those having only two-anthered stamens. Mr Bentham divides it into three sub-orders, according to the inflorescence, each of which is again subdivided into several tribes.

The majority of this family contain a principle more or less acrid, purgative in some, and poisonous, as in the foxglove, unless taken in small doses. The meadow eyebright (*Euphrasia officinalis*) is slightly astringent and aromatic, without the deleterious qualities of the other genera. Cows are said to be fond of *Melampyrum pratense*; and Linnæus says the best and yellowest butter is made where it abounds. One or two species of Linaria and Calceolaria are named as yielding colours for the dyer. *Mimulus luteus* affords an interesting example of an exotic plant—from America—becoming speedily diffused throughout Europe in a naturalised state. It is now not

uncommon in ditches. Its stigma, formed of two lips, displays peculiar irritability.

LABIATÆ.—A very large natural order, remarkable for the uniformity of structure and properties which prevails among the members. The *labiate* or lipped corolla immediately suggests the mint, sage, thyme, dead-nettle, horehound, and lavender, with which every one must be more or less familiar. They are herbs or under-shrubs, with quadrangular stems, and opposite, divided or undivided, exstipulate leaves, replete with receptacles of aromatic oil. The flowers are in opposite, nearly sessile, axillary verticillasters, resembling whorls, as in the dead-nettle; sometimes solitary; calyx, tubular and persistent; corolla, bilabiate, the upper lip (*a*) being entire or bifid, the lower (*b*) three-cleft, the upper in estivation overlapping the lower; stamens, four, didynamous, the upper sometimes wanting; ovary, deeply four-lobed, seated on a fleshy disc, each lobe containing one erect ovule; style, simple; stigma, bifid; fruit, from one to four small nuts inclosed within the persistent calyx.

Labiatæ.

The following plants well exemplify the order: *Lamium album*, the white dead-nettle of our wall-sides; *Salvia officinalis*, the common garden sage; *Rosmarinus officinalis*, the well-known rosemary shrub; *Thymus Serpyllum*, the wild thyme; *Lavandula vera*, the sweet-scented lavender; *Mentha viridis*, spearmint, and *M. piperita*, peppermint; *M. sylvestris* is the Greek Heduosmon, translated mint in Scripture; *Nepeta Glechoma*, the ground ivy; *Marrubium vulgare*, the true medicinal horehound; *Ballota nigra*, black horehound, well known for its heavy oppressive smell; *Prunella vulgaris*, self-heal; *Ajuga reptans*, the common bugle; with basil, marjoram, betony, hyssop, and other culinary and medicinal herbs.

ACANTHACEÆ.—There are nearly 100 genera enumerated under this order, and upwards of 1400 species of herbs and shrubs, principally inhabiting tropical regions. Leaves, simple, opposite, and without stipules; inflorescence, terminal or axillary; flowers, showy, in spikes with two or three bracts to each; calyx, in four or five divisions, and persistent—but in many of the species inconspicuous or obsolete, its place being supplied by the large bracts; corolla, monopetalous, and usually irregular, with the limb ringent or bilabiate, and deciduous; stamens, two or four, and in the latter case didynamous; anthers, one or two celled, sometimes bearded, as in Acanthus, and bursting longitudinally; style, simple; stigma, one or two lobed; fruit, a two-celled capsule, elastically two-valved; seeds, supported on a filiform podosperm. The elastic dehiscent capsules, wingless seeds with hooked dissepiments, and imbricated flowers, are distinguishing features.

Examples of the genera are—*Acanthus*, *Thunbergia*, *Goldfussia*, *Lankesteria*, *Ruellia*, and *Justicia*. The species of Acanthus are found chiefly in the south of Europe; they are plants with graceful foliage, and the leaves of the *A. mollis* is said to have furnished Callimachus with patterns for the capital of the Corinthian pillar. The corolla varies considerably in the different genera; being bilabiate in Justicia, funnel-shaped in Ruellia, and campanulate in Thunbergia, the species of which are exotic climbers.


Acanthus.

The properties of the order are little known. The Arabs use the leaves of an Acanthus by way of salad; *Justicia pectoralis*, boiled in sugar, yields a syrup used in the West Indies as a stomachic; and *J. paniculata* is said to be the basis of the famous French tonic, *Drogue Amère*. A valuable deep blue dye is said to be obtained from one of the East Indian Ruellias.

MONOCHLAMYDEÆ.

The plants in this division have either no floral envelope, or have one only. In the former case, the pistil and stamens are naked; in the latter, they are surrounded by a calyx, there being no parts corresponding to the petals of a true corolla. The following are the orders:

ANGIOSPERMÆ.

Nyctaginaceæ—Marvel of Peru order.
*Amaranthaceæ—Amaranths.
*Chenopodiaceæ—Goosefoots.
Basellaceæ—Basella order.
*Scleranthaceæ—Knawel order.
Phytolaccaceæ—Phytolaccads.
Petiveriaceæ—Petivera order.
*Polygonaceæ—Buckwheats.
Begoniaceæ—Begoniads.
Lauraceæ—Laurels.
Atherospermaceæ—Plume Nutmegs.
Myristicaceæ—Nutmegs.
Monimiaceæ—Monimia order.
Proteaceæ—Protea order.
*Elæagnaceæ—Oleaster.
Penæaceæ—Penæa order.
*Thymelæaceæ—Mezereons.
Aquilariaceæ—Aquilaria order.
Chailletiaceæ—Chailletia order.
Samydaceæ—Samyda order.
Homaliaceæ—Homalium order.
*Santalaceæ—Sandal-woods.
*Aristolochiaceæ—Birthworts.
Nepenthaceæ—Pitcher plants.
Datiscaceæ—Datisca order.
*Empetraceæ—Crowberries.
*Euphorbiaceæ—Spurgeworts.
Scepaceæ—Scepa order.
*Callitrichaceæ—Starworts.
*Ceratophyllaceæ—Hornworts.
*Urticaceæ—Nettleworts.
Artocarpaceæ—Bread-fruits.
*Ulmaceæ—Elms.
Stilaginaceæ—Stilago order.
Lacistemaceæ — Lacistema order.
Podostemonaceæ—River-weeds.
Chloranthaceæ—Chloranthads.
Saururaceæ—Lizard's tails.
Piperaceæ—Peppers.
*Myricaceæ—Gale order.
*Salicaceæ—Willows.
Altingiaceæ—Liquidambars.
*Betulaceæ—Birches.
*Corylaceæ—Hazels and Oaks.
Casuarinaceæ—Beefwoods.
Platanaceæ—Plane-trees.
Juglandaceæ—Walnuts.
Garryaceæ—Garrya order.
Rafflesiaceæ—Rafflesia order.
Cytinaceæ—Cistus Rapes.
Balanophoraceæ—Balanophoras.

GYMNOSPERMÆ.

*Coniferæ — Pines or Cone-bearers.
*Taxaceæ—Yews.
Gnetaceæ—Jointed Firs.
Cycadaceæ—Cycad and Zamia order.

ANGIOSPERMÆ.

CHENOPODIACEÆ.—Chiefly herbs with herbaceous (greenish) flowers. The embryo is coiled round mealy albumen, or spiral without albumen; ovary, free, one-celled; stamens, inserted into the base of the perianth. Many of the species are used as pot-herbs, such as Spinach, Orach, and English mercury (*Chenopodium Bonus-Henricus*). The seeds of *C. Quinoa* are used as food. The Beet (*Beta vulgaris*) yields a large proportion of sugar, and in the form of mangold-wurzel is an important forage plant throughout Europe.

LAURACEÆ.—An important order, comprising about 450 species. They are tropical trees, with elegant foliage and aromatic properties, having exstipulate, alternate (seldom opposite) leaves, with inconspicuous flowers. The perianth is from four to six cleft, the limb sometimes obsolete; estivation, imbricate. The male and female flowers are distinct: the former have four, six, or eight stamens, opposite the segments of the perianth; the latter have four or more abortive stamens, furnished with glands, but without anthers, a one-celled, one-seeded ovary, with a simple style and an obtuse-crested stigma. The fruit is fleshy and indehiscent, naked, or covered by the enlarged and fleshy perianth. The two or four celled anthers, with the valves curling upwards when ripe, and the filaments furnished with kidney-shaped glands at their base, are characteristics of the order.

The chief genera are—*Laurus*, the sweet bay; *Sassafras*, the sassafras-tree; *Persea*, the avocado-pear; *Camphora*, the camphor-tree; *Cinnamomum*, the cinnamon-tree; *Cassytha*, the Dodder-laurel; *Tretranthera*, and *Cryptocarya*. The true laurels have two anthers, and naked fruit; the cassia, cinnamon, and camphor have four anthers, and the fruit covered. The plants contain essential oil in abundance, which imparts to them a peculiar sweet, though strong penetrating odour, and a warm and pleasant taste; hence they yield some of our most grateful stimulants and spices. Cinnamon, cassia, camphor, benzoin, and sassafras are products of the family; the roots of the sweet bay yield a violet dye; and a concrete oil, used in candle-manufacture, is obtained from the fruit of *Laurus glauca*. The branches of *Laurus nobilis*, or sweet bay, were used to crown the victors in the ancient games. This plant seems to be the *ezrach* of the Bible, translated 'green bay-tree.'

ARISTOLOCHIACEÆ.—There are only six or eight genera in this order, the members of which are herbaceous plants or shrubs, of climbing habit. The characters are—flowers, hermaphrodite; perianth, tubular, adherent with the ovary, and divided into three segments; stamens, from six to twelve epigynous, sometimes free and distinct, in other cases adhering with the style and stigma; ovary, three to six celled; style, short; stigma, six-rayed; fruit, capsular, dry, or succulent, three to six celled, and many-seeded; seeds, thin, flat, and of a dark-brown colour.

The chief genera are—*Aristolochia*, the birthwort; and *Asarum*, the wild-ginger of North America. Many of the species are natives of Europe; but they abound in the tropical regions of South America; *Arist. Clematitis* (common birthwort) and *Asar. Europæum* (Asarabacca) are the only two found in Britain, and are doubtfully native.

The birthworts are heating and stimulating in

Aristolochia.

their properties, and act chiefly on the skin and kidneys. The prepared root of *Arist. serpentaria* (Virginian snake-root) is used in ague, typhus fever, and in gout—being one of the ingredients of the celebrated Portland powder. The snake-root is regarded as an antidote against serpent-bites. A drop or two of the juice, if introduced into the mouth of one of these reptiles, has the power of stupefying it, so that it can be handled with impunity; and a few drops swallowed almost instantly cause death. The roots of the species of *Asarum* have bitter and acrid properties, and a disagreeable odour like that of the stapelias. *Asarum canadense* has an aromatic flavour, and is often used by the country-people in lieu of the true ginger.

EUPHORBIACEÆ.—In Britain, this order is represented by the small weedy spurges of our gardens and waste grounds, but exhibits a nobler aspect in hot regions, where the tall cacti-like columnar species attain gigantic proportions. The juice is usually acrid and milky, and the fruit formed of three globose carpels in union. The purgative resin Euphorbium is supplied by *E. officinarum* and other species. *Hura crepitans* is the sand-box tree, whose fruit bursts with a loud noise. *Ricinus communis* yields castor-oil. The vegetable tallow of China is derived from *Stillingia sebifera*. The seeds are beaten down and boiled to separate the tallow, which fuses at 80°, and is used for candles. *Aleurites triloba* yields Eboe-oil, used by artists. *Croton Tiglium* seeds yield croton-oil. *Janipha manihot* is the cassava or manioc plant of the West Indies. *Jatropha Curcas* produces the physic-nut. *Oldfieldia Africana* is the tree which supplies the African teak or oak.

URTICACEÆ—ARTOCARPACEÆ.—These are extensive orders of plants, which, to the uninitiated, may appear very dissimilar—as illustrated, for example, by the common nettle, the hop, the hemp, the pellitory of the wall, the bread-fruit tree, the cow-tree, upas, mulberry, common fig, banyan, and India-rubber tree, all of which, though exhibiting different habits and products, are not only strikingly alike in their essential characters,

but also in their general properties. They are much simplified by subdivision into two orders—namely, *Urticaceæ* and *Artocarpaceæ*—the former including the herbaceous species—as the nettle, hemp, and hop, with watery juice; and the latter the ligneous species—as the bread-fruit, mulberry, and fig, which have their juice milky. Bearing this distinction in mind, the following may be stated as the characteristics common to both: Trees, shrubs, or herbs, with alternate leaves, sometimes covered with asperities or stinging hairs, and furnished with membranous stipules, which are deciduous or convolute in vernation; flowers, usually monœcious, sometimes diœcious; perianth, membranous, lobed, and persistent; stamens, definite, distinct, inserted into the base of the perianth, and opposite its lobes; anthers, turned backwards with elasticity when bursting; ovary, superior, simple; ovule, solitary, erect, or pendulous; stigma, simple; fruit, a simple indehiscent nut, as in the nettle and hemp—or consisting of achenes immersed in a fleshy receptacle, or the persistent fleshy perianths, as in the bread-fruit, or inclosing them within its cavity, as in the fig. 'The unisexual flowers,' says Dr Lindley, 'simple lenticular fruit, and superior radicle and stipules, afford the essential characteristics of this order, which cannot well be mistaken for any except *Chenopodiaceæ;* and the plants of that order never have stipules, or rough or stinging leaves.'

The chief genera in the order URTICACEÆ are —*Urtica*, of which *U. dioica* is the common stinging-nettle; *U. urens*, the smaller stinging-nettle; and *U. pilulifera*, the Roman nettle; *Humulus lupulus*, the cultivated hop; *Cannabis sativa*, the fibrous hemp of commerce; and *Parietaria erecta*, the pellitory of the wall. The members of this order are widely scattered over the world, and increase apparently with the progress of civilisation; some of them—as, for example, the nettles—following in the footsteps of man. The chief genera of the order ARTOCARPACEÆ are—*Artocarpus*, of which *A. incisa* is the bread-fruit of the South Sea Islands; and *A. integrifolia*, the jack-tree of the East India Islands; *Galactodendron utile*, the cow-tree or palo de vaca of South America; *Antiaris toxicaria*, the upas-tree of Java, about which so many fabulous stories have been told; *Morus*, of which *M. nigra* is the common black mulberry, *M. rubra*, the red, and *M. alba*, the white mulberry, the leaves of which are so much esteemed for feeding silkworms; *Ficus*, of which *F. Carica* is the common edible fig, *F. Sycamorus*, the sycamore fig, the wood of which is very durable, and is supposed to have been used in the construction of mummy-cases; *Urostigma*, of which *U. Indica* is the spreading banyan, *U. elasticum* the India-rubber tree, and *U. religiosum* the sacred fig or pippul-tree of India. *Bœhmeria* (*Urtica*) *nivea*, the China nettle, is the source of that beautiful fabric for handkerchiefs, &c. which has of late years come into use under the name of China-grass and China nettle-fibre. Large quantities of the fibre are produced in the East, and find a ready sale in European markets, and especially among European residents in hot countries, for whose clothing this extremely fine fibre is peculiarly adapted.

The Urticaceæ have watery juice, which is acrid and astringent, and the fibres of their stems are all less or more tenacious. The leaves of the hemp are narcotic; the hop (fig.) has bitter, aro-

Hop.

matic, and stomachic properties, and its effluvia are said to be narcotic. The stinging property of the common nettle is well known. In the Artocarpaceæ, the juice is milky, and on exposure to the air, becomes tough and elastic. Their fruit is edible, but their juice is generally acrid and poisonous; except in that of the Galactodendron, which is wholesome and nutritious. The elaboration of a tough elastic product seems to be characteristic of the whole order—making its appearance in the stem of the hemp, in the inspissated juice of the India-rubber tree, or in silk, the best of which is derived from silkworms which feed on the leaves of the mulberry.

BETULACEÆ.—A small order of trees and shrubs, abounding in the temperate and colder regions of the globe. They have alternate simple leaves, with the primary veins often running straight from the midrib to the margin, and deciduous stipules. The flowers are in catkins, unisexual, and monœcious; the males having small scales in place of a perianth, or, in Alnus, a four-leaved membranous perianth. Stamens distinct, opposite the scales, scarcely ever monadelphous; anthers, two-celled; ovary, two-celled; ovules, definite, pendulous; style, single or none; stigmas, two; fruit, membranous, indehiscent, by abortion one-celled; seeds, pendulous, naked.

The chief genera are *Betula*, the birch, and *Alnus*, the alder, the species of which abound in every northern country. The common white birch (*B. alba*) is an elegant tree, thriving in almost any sort of soil, and becoming stunted and dwarfish only in the arctic regions, or at great elevations. The weeping-birch is a still more graceful tree, grown in lawns and parks for its fine drooping branches and neat foliage. *B. nana* is the dwarf birch of high and exposed situations, being found on the Scottish mountains and in some countries approaching to the very limits of perpetual snow. *B. nigra* is the black birch of North America, the timber of which is used by cabinet-makers; and *B. papyracea* is the paper birch, whose bark

is used by the Esquimaux and others in the construction of canoes. The common alder (*A. glutinosa*) is a quick-growing tree, found in swampy flats and by the borders of streams; its wood resists well the action of water, and is useful for piles; the Rialto at Venice is built on alder-piles, as well as many houses in Amsterdam; the hoary alder (*A. incana*) is seldom found south of the sixtieth parallel; the notch-leafed alders (*A. sinuolata* and *A. glauca*) are both American species.

The bark of the order is astringent and bitter. A decoction of birch-bark is used by the Laplanders in the preparation of reindeer skins; and the empyreumatic oil derived from it is used by the Russians in tanning, which gives the peculiar odour of their leather. The sweetish sap obtained by tapping the birch in spring is the chief ingredient in birch-wine; the leaves, which, when young, are highly odorous, are also used in imparting dyes of various shades of yellow. *B. lenta* yields sugar.

CORYLACEÆ.—The Corylaceæ or Cupuliferæ are so named from the cup-like shape of the persistent involucre in which their fruit or nuts are placed—as, for example, the acorn. The order includes many genera of well-known trees and shrubs—as the oak, Spanish chestnut, beech, hazel, and hornbeam. Their leaves are alternate, simple, and stipulate; their venation well marked, and often rigid; flowers, unisexual; the males in catkins, and the females in clusters or in catkins; the male flowers have from five to twenty stamens inserted into the base of the scales, or of a membranous perianth, generally distinct; in the females, the ovaries are crowned by the rudiments of an adherent perianth, seated within a coriaceous involucre of various figure, and with several cells and several ovules, most of which are abortive; ovules, twin or solitary, pendulous; stigmas, several, nearly sessile, and distinct; fruit, a bony or leathery nut, of one cell, and more or less inclosed in the involucre.

The following are the most familiar genera: *Quercus*, of which *Q. pedunculata* and *sessiliflora* are the British oaks; *Q. suber*, the cork-tree; *Q. Ilex*, the evergreen oak; *Q. rubra*, the scarlet oak of America; *Q. infectoria*, the gall-yielding oak; and *Q. coccifera*, the kermes oak. *Fagus*, of which *F. sylvatica* is the common beech of our woods; and *F. ferruginea*, of North America, has edible fruit. *Castanea*, to which belong *C. vesca*, the edible sweet chestnut; and *C. pumila*, the dwarf Virginian chestnut. *Corylus*, of which *C. Avellana* is the common hazel-nut or filbert, which yields an oil used by artists and watch-makers. *Carpinus Betulus*, the hornbeam of our hedges; and *Ostrya Virginica*, the iron-wood of America. The hornbeams are by some botanists ranked under the Birch tribe, on account of the involucre not forming so complete a cupule as the other genera; but this seems too minute a distinction, as the involucre is not more leafy than it is in some of the filberts. The members of the family abound in Europe, Asia, and North America, and generally in temperate regions, more sparingly in South America; they are altogether absent from the south of Africa.

The bark in all the species is bitter and astringent, and is used for dyeing, tanning, and for medical purposes. In a few, the fruit is bitter and disagreeable; but in the majority it is farinaceous, and frequently contains an oily matter, used in domestic economy. Their fruit, as well as their bark and timber, is of the highest value to man. The gall-nut is an excrescence of the oak caused by the puncture of an insect; it is used in medicine, and in the manufacture of ink and black dyes.

GYMNOSPERMÆ.

CONIFERÆ.—One of the most important, as it is one of the best defined, of the natural orders. Its members are trees or shrubs, with a symmetrically branched trunk abounding in resin, and are familiarly illustrated by the Scotch pine, the spruce and silver firs, the larch, the cedar, the araucaria, the arbor vitæ, the cypress, and the juniper. The ligneous tissue of their wood is marked with circular discs having a central punctation; their leaves are linear, needle-shaped, or lanceolate, entire at the margin. The characters afforded by the fructification are: Flowers, unisexual; males in deciduous catkins, monandrous or monadelphous, each floret consisting of a single stamen, or of a few; females in cones, whose scales arise from the axil of membranous bracts supplying the place of ovaries; destitute of a proper style or stigma; ovules, naked, in pairs on each scale, with large micropyles at their apices; fruit consisting of a cone formed of the hardened scales, which become enlarged and indurated, and occasionally of the bracts also; seed, with a hard crustaceous testa. In speaking of the Coniferæ, it has been not inaptly remarked that 'the flowers are quite different from what is generally understood by that name, being in fact nothing but scales; those of the male containing the pollen in the body of the scale, and those of the female producing the ovules or incipient seeds at the base.'

Well defined as the order obviously is, there are minor distinctions which warrant its subdivision into the following sections—namely, ABIETINEÆ, the true pines and firs; and CUPRESSINEÆ, the cypresses. In the firs, the fruit is a cone, the scales of which open, and more or less recurve, when the seeds are ripe; the ovules are inverted; the pollen, oval, or curved: in the cypresses, the fruit is also a cone, but rounder, and with fewer scales, occasionally succulent, forming a galbulus; ovules, erect; pollen, spheroidal. Of the Abietineæ the following are characteristic members: *Pinus sylvestris*, the Scotch pine; *Abies excelsa*, the spruce-fir; *Picea pectinata*, the silver fir; *Larix Europæa*, the common larch; *Cedrus Libani*, the cedar; and *Araucaria imbricata*, the Chili pine—all of which are evergreens, with the exception of the larch. The Cupressineæ are well represented by *Cupressus sempervirens*, the evergreen cypress; *Thuja occidentalis*, the American arbor vitæ; *Taxodium distichum*, the deciduous cypress; *Juniperus communis*, the juniper of our moors; *J. sabina*, the savin-tree, as well as by the newer genera, *Saxe-Gothæa*, *Fitzroya*, &c.

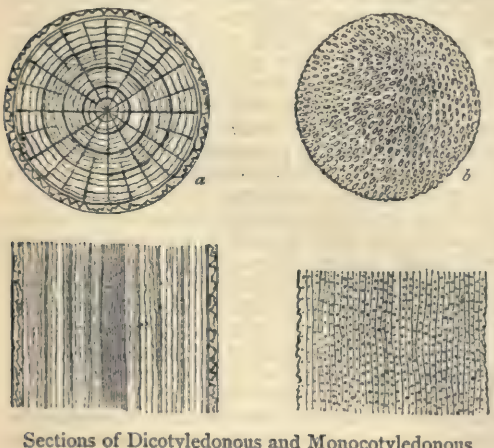
The high importance of this order is derived from its timber, which in all is straight, easily worked, and durable. *Wellingtonia gigantea*, the mammoth tree of California, forms a lofty trunk 112 feet in circumference, and upwards of 350 feet in height. Many valuable additions have

been made to this order of late years by Douglas, Jeffrey, Murray, Brown, and others. Vast forests of pines occur in North America, which have yielded many species well adapted to our climate, such as *Abies Douglasii*, *Pattoniana*, *Pinus Balfouriana*, *M'Nabiana*, *Jeffreyi*, &c.; and indeed almost every gentleman's estate exhibits examples of this order, not only from America, but from almost every region in the world. The deodar and cedar, from the East; firs, cypresses, and junipers, from the Far West; araucarias, from Chili and the antipodes; and cryptomerias, from Japan, form by far the most interesting, the most useful, and the most ornamental of our forest trees, whether planted merely with a view to the raising of timber, or for the purpose of beautifying the landscape. (See ARBORICULTURE.) Many plants of the order are also valuable for their resinous productions; several kinds of pitch, tar, turpentine, gums, and balsams being procured from them. The large seeds of some are edible and wholesome; the succulent cones, or, as they are familiarly called, *berries* of the juniper are largely used in the preparation of gin; and the main ingredient in spruce-beer is an extract from several species of Abies. Great tanning-powers exist in the bark of the larch; the savin, juniper, and others, possess stimulating and diuretic properties.

TAXACEÆ.—The yews are nearly related to coniferæ, and are usually associated with them. They differ in not producing true cones. The wood of many species is also peculiar, having spirals on the woody tubes, as well as discs; but this we have recently ascertained to be also the case in some firs—such as *Abies Douglasii*.

ENDOGENOUS OR MONOCOTYLEDONOUS PLANTS.

This class includes those plants whose leaves have their veins placed parallel—as the palms, the grasses, the hyacinth and crocus, and whose stems have no distinction of pith, wood, bark,



Sections of Dicotyledonous and Monocotyledonous Stems.

concentric circles, and medullary rays, like the Exogens (*a*), but consist merely of a confused mass of tissue (*b*). Their seed contains an embryo, having only one seed-lobe or cotyledon; hence the term Monocotyledon. Their trunks increase inwardly, instead of by external concentric layers; hence also the term Endogen. They are divided into three sections—DICTYOGENÆ, differing from all the others in having the leaves more or less net-veined, and usually articulated with the stem. PETALOIDEÆ, or FLORIDÆ, those having a perianth—such as the orchis, lily, palm, &c. GLUMIFERÆ, those which are destitute of a perianth, but have glumes or husks instead, like the grasses. The trees of this division are strictly tropical; the herbaceous species are found all over the globe.

§ 1. DICTYOGENÆ.

*Dioscoreaceæ—Yam order.
Smilaceæ—Sarsaparilla order.
*Trilliaceæ—Trillium order.
Roxburghiaceæ—Roxburghia order.
Philesiaceæ—Philesia order.

§ 2. PETALOIDEÆ.

*Hydrocharidaceæ—Frog-bits.
*Orchidaceæ—Orchids.
Apostasiaceæ—Apostasia order.
Burmanniaceæ—Burmannia order.
Zingiberaceæ—Ginger order.
Marantaceæ—Arrow-roots.
Musaceæ—Bananas.
*Iridaceæ—Iris order.
*Amaryllidaceæ—Amaryllis order.
Hypoxidaceæ—Hypoxids.
Hæmodoraceæ—Blood-roots.
Taccaceæ—Tacca order.
Bromeliaceæ—Pine Apples.
*Liliaceæ—Lilies.
*Melanthaceæ—Colchicum order.
Gilliesiaceæ—Gilliesia order.
Pontederiaceæ—Pontederia order.
Xyridaceæ—Xyris order.
Philydraceæ—Waterworts.
Commelynaceæ—Spiderworts.
Mayacaceæ—Mayaca order.
*Juncaceæ—Rushes.
Palmaceæ—Palms.
*Alismaceæ—Water-plantains.
*Juncaginaceæ—Arrow grasses.
*Butomaceæ—Flowering-rushes.
Pandanaceæ—Screw-pines.
*Typhaceæ—Bulrushes.
*Araceæ—Arum order.
*Orontiaceæ—Sweet Flags.
Pistiaceæ—Duck-weeds.
*Naiadaceæ—Pond-weeds.
Triuridaceæ—Triuris order.
*Restiaceæ—Restio order.
*Eriocaulonaceæ—Pipeworts.
Desvauxiaceæ—Bristleworts.

§ 3. GLUMIFERÆ.

*Cyperaceæ—Sedges.
*Gramineæ—Grasses.

DICTYOGENÆ.

DIOSCOREACEÆ.—These are twining, somewhat shrubby plants, with unisexual flowers in spikes, natives of the tropics, except *Tamus communis*, or Black Bryony, which represents the order in temperate climates. Various species of *Dioscorea* yield edible tubers, which are known by the name of yams, and are used like potatoes. *D. Batatas* is the Chinese Potato. *Testudinaria Elephantipes* is the Elephant's-foot, Hottentot's-bread, or Tortoise plant, of the Cape.

PETALOIDEÆ.

ORCHIDACEÆ.—This order consists of terrestrial or epiphytal herbaceous plants with enlarged roots and stems. The roots in epiphytal species are clothed with an outer layer of spiral cells, which apparently serve the purpose of absorbing moisture from the atmosphere, and thus enabling the plant, which has no roots in the soil, to subsist and develop itself. The perianth consists of six segments in two rows, one differing in form from the rest, and called the labellum. The pollen-cells do not occur in the form of distinct grains, but are aggregated together in simple or compound *masses*, which become detached collectively. The flowers often resemble the forms of insects, as the bee orchis of Kent, and the more gaudy butterfly orchid of the tropics. The singular forms and intense colours of their flowers recommend these plants to the attention of horticulturists. Of the 3000 existing species, few are conspicuous for their uses. Species of *Eulophia* furnish salep; and the fragrant vanilla, used in confectionary and in the

preparation of chocolate, is obtained from *Vanilla planifolia* and *aromatica.*

BROMELIACEÆ.—This family consists of about a dozen genera, and more than 170 species of plants, with scarcely any stem, and sometimes epiphytic in their habit. Their leaves are rigid, channeled, and often spiny or toothed at the margin. The perianth is tubular, its parts in two rows; the outer, or calyx, in three clefts, rigid, and persistent; the inner, petaloid and deciduous; stamens, six, inserted into the tube of the perianth; ovary, free or cohering, and three-celled; ovules, indefinite; style, single; stigma, three-parted, often twisted; fruit, capsular or succulent, three-celled, and many-seeded.

The principal genera are—*Bromelia*, *Ananassa*, *Billbergia*, *Pitcairnia*, *Tillandsia.* They are natives of moist warm climates. The common pine-apple (*A. sativa*) receives its English name from the circumstance of its fruit being covered on all sides with small triangular scales, resembling the cone of a pine-tree. What is called the fruit is, in fact, the fruits of the same spike cohering into one mass, by means of their succulent bracts.

The order has several important uses. Several of the species are esteemed for their showy blossoms; and the tough leaf-fibres of many produce excellent cordage. Some of the Tillandsias, which hang their black thread-like festoons from the trees of Brazil, are collected and used for stuffing mattresses, saddles, &c. Most of the genera yield a fine aromatic odour; and from their habit of retaining water in the sheathing axes of their leaves, are said to be specially grateful to the traveller in the regions where they abound.

LILIACEÆ.—A very extensive, and, to the florist, one of the most important of the natural orders. Taking the common white lily as the type, there is a great resemblance in all the Lilyworts, not only in their habits and forms, but also in their essential characters; but botanists have somewhat perplexed themselves by subdivisions founded upon minute differences. It must be confessed that the limits of the order are not very clearly defined. The plants may be generally characterised as having usually scaly or tunicated bulbs; and leaves not articulated with the stem, either sessile or with a narrow petiole. In some of the genera, the flowers are erect and single, as in the tulip; in others, they are erect, but in umbels, as in the orange-lily; and in others they are in racemes and drooping, as in yucca; or single and drooping, as in the fritillary; or with the segments curved back, as in the martagon lily. Perianth, coloured, regular, and divided into six segments, occasionally tubular; stamens, six, inserted into the segments of the perianth; anthers, opening inwards; ovary, superior, three-celled, and many-seeded; style, one; stigma, simple or three-lobed; fruit, either a three-celled, three-valved capsule, or fleshy, and then occasionally tripartite. The seeds of the Asphodeleæ have a black, crustaceous, brittle testa; in the Tulipeæ and Hemerocallideæ the testa is brown and spongy.

Liliaceous Flower.

The following plants may be mentioned as illustrative of the principal genera: *Lilium chalcedonicum*, the scarlet martagon lily, supposed to be the Krinon, or lily of the field of the New Testament; *Tulipa sylvestris*, the wild yellow tulip; *Allium cepa*, the onion; *Fritillaria Meleagris*, the fritillary; *Hyacinthus orientalis*, the garden hyacinth; *Endymion nutans*, the bluebell; *Asparagus officinalis*, the garden asparagus; *Muscari racemosa*, the grape hyacinth; *Erythronium dens-canis*, the dog's-tooth violet; *Phormium tenax*, the New Zealand flax; *Aloë*, the aloe; *Hemerocallis*, the day-lily; *Scilla*, squills; *Asphodelus*, king's spear; *Ornithogalum umbellatum*, the star of Bethlehem or doves' dung of Scripture. The Lilyworts are found in every quarter of the globe, being more abundant, however, in temperate than in tropical climates, where they exist chiefly in arborescent forms.

The properties of the order present considerable differences. All the Asphodeleæ contain a bitter stimulant principle, and have a viscid juice, as is exemplified by the onion, garlic, leek, and chives. The roots of some are purgative, as the aloe; while those of several lilies are eaten in Siberia. Gum-dragon is the styptic juice of *Dracæna Draco*, which yields a gum called Dragons' Blood; New Zealand flax is the tough fibre of the leaf of *Phormium tenax;* squills is a well-known demulcent; and the succulent suckers of asparagus are largely eaten as a vegetable. *Xanthorhœa hastile* and *arborea* are the grass-trees of New South Wales, which yield a resin used by the natives for fixing wooden handles to stone hatchets or hammers.

PALMACEÆ.—An important order of arborescent plants, with lofty, usually unbranched trunks, bearing a tuft of leaves on the summit. The leaves are large, pinnate or fan-shaped; flowers, small, arranged on a simple or branched spadix, which is inclosed in a one or many valved spathe; florets, bisexual or polygamous; perianth, six-parted, and persistent, its parts in a double row—the three outer segments often smaller, the three inner sometimes deeply connate; stamens inserted into the base of the perianth, usually six, seldom three, and in a few polygamous species, indefinite; ovary, one or three celled, or deeply three-lobed; ovules, three, rarely one; fruit, a nut, drupe, or berry; albumen, cartilaginous or hard, often ruminate, with a central cavity.

Palm.

The principal genera are—*Cocos*, the coco-nut; *Phœnix*, the date-palm; *Sagus*, the sago-palm; *Calamus*, the rattan canes; *Areca*, the betel-nut; *Borassus*, the Palmyra-palm; *Ceroxylon*, the wax-palm; *Elais*, the oil-palm; *Lodoicea*, the double coco-nut; *Phytelephas*, the vegetable ivory-palm; and *Hyphœne*, the doom-palm of Egypt. They are strictly inhabitants of the tropics, to the natives of which they are undoubtedly the most useful order of vegetation.

The properties of the Palms are numerous and varied—wine, oil, wax, flour, sugar, salt, thread, utensils, habitations, and food, being obtained from numerous species. *Coir*, which is worked into mats and cordage, is the dry fibrous pericarp of the coco-nut.

BUTOMACEÆ.—A small order of aquatic plants, having very cellular leaves, furnished with parallel veins, and handsome umbellate flowers of a purple or yellow colour. Calyx, three-sepaled, usually herbaceous; corolla, three-petaled and coloured; stamens, definite or indefinite; ovaries, superior, three, six, or more, either distinct or united; follicles, many-seeded; seeds, minute, attached to the whole inner surface of the fruit.

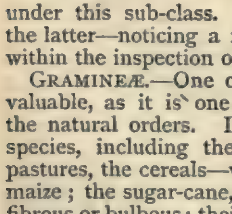
The genera are—*Butomus*, *Limnocharis*, and *Hydrochleis*, which abound respectively in the marshes of Europe, South America, and the East Indies. *B. umbellatus*, the flowering rush, an enneandrous plant, is found in ditches and by river-sides in some parts of Britain, growing from two to three feet high, with sword-shaped leaves, and umbels of rose or purplish white flowers. *Limnocharis Plumieri*, a native of Brazil, has yellow flowers, and the apex of each leaf is furnished with a curious pore, apparently for the discharge of the superabundant moisture which constantly distils from the plant.

Flowering Rush.

The order is said to possess acrid and bitter properties; and most of the species yield a milky juice.

GLUMIFERÆ.

The plants in the section Glumiferæ of the Monocotyledons are destitute of a regular calyx and corolla, having instead green or brown scales to cover the stamens and pistil. The glume or chaff of the oat (see fig.) is a familiar example of this kind of envelope. The Sedges (CYPERACEÆ) and the Grasses (GRAMINEÆ) are the only orders ranking under this sub-class. We can merely glance at the latter—noticing a few of the genera which lie within the inspection of every one.



GRAMINEÆ.—One of the most important and valuable, as it is one of the most extensive, of the natural orders. It comprehends 4000 known species, including the common grasses of our pastures, the cereals—wheat, barley, rye, oats, and maize; the sugar-cane, rice, &c. Their roots are fibrous or bulbous; their culms or stems cylindrical and hollow, except at the joints, where they become solid, the whole culm generally covered with a silicious coating; leaves alternate, and though sheathing the stem, not united round it; flowers in spikelets, and arranged in a spiked, racemed, or panicled manner. The characters of the fructification are —flowers, either solitary or arranged in spikes, usually hermaphrodite, sometimes monœcious or polygamous, consisting of imbricated bracts, of which the most exterior are called *glumes*, the inferior immediately inclosing the stamens, *paleæ*, and the innermost at the base of the ovarium, *scales:* glumes, usually two, alternate, sometimes single, often unequal; paleæ, two, alternate, the lower or exterior simple, the upper or interior supposed to be composed of two united by their contiguous margins, and usually with two keels; scales, two or three, sometimes wanting; stamens, hypogynous; anthers, versatile; pericarp, usually undistinguishable from the seed, membranous; albumen, farinaceous.

The Grasses are scattered all over the globe, and are the most directly useful of all vegetation both to man and to the lower animals. The following well-known plants may be taken as illustrative of the order: *Triticum vulgare*, common wheat, which, according to the experiments of Fabre, appears to have originated from a small weedy grass (*Ægilops ovata*), not uncommon on the shores of the Mediterranean. *Hordeum distichum*, common two-rowed barley; *Secale cereale*, rye; *Avena sativa*, common oat; *Zea mays*, maize or Indian corn; *Saccharum officinarum*, the sugar-cane; *Oryza sativa*, rice; *Bambusa arundinacea*, the bamboo; *Phleum pratense*, cat's-tail or Timothy grass; *Anthoxanthum odoratum*, sweet-scented vernal grass; *Dactylis glomerata*, cock's-foot grass; *D. cæspitosa*, the tussac-grass; *Andropogon Schœnanthus*, the lemon-grass; *Gynerium argenteum*, the Pampas-grass; *Phalaris canariensis*, the canary-seed; Sorgham species, the guinea-corn; *Festuca pratensis*, meadow-fescue; *Lolium perenne*, rye-grass; *Briza media*, quaking-grass; *Alopecurus pratensis*, meadow fox-tail grass; and *Holcus lanatus*, woolly soft grass. The cereal grains are plants of very ancient cultivation, and not being now found in a wild state, the origin of some of them is doubtful. Though allied in many respects to the Sedges, the Grasses are readily distinguished by their round hollow-jointed stems, and leaves that sheathe, but do not completely surround, the stem like a tube. The Grasses have a thin silicious coating on their stems, which seems intended to furnish them with greater strength and durability than could have been procured by simple ligneous fibre.

Sugar-cane.

ACROGENOUS OR ACOTYLEDONOUS (FLOWERLESS) PLANTS.

This class of vegetation is readily distinguished by none of its members bearing proper flowers—hence the terms *Cryptogamia* and *Flowerless.* The higher forms exhibit a peculiar kind of tissue, called scalariform vessels, as well as spiral vessels; but the lower forms consist of cellular tissue only. They exhibit very different degrees of organisation—the highest (*ferns*) having both stems and leaves (*fronds*), and the lowest consisting of simple-jointed threads, or even mere individual cells. Between these two extremes there are various

conditions of stem and leaf—the two most frequently graduating into each other, and forming neither true leaf nor stem, but thin expansions, termed *thalli*. Cryptogamic plants do not originate from seeds, containing embryos, like the flowering-plants, but are reproduced by means of spores—bodies which in their simplest form consist of a single cell, but which are very varied in morphological character in different families. There are two sub-classes.

§ 1. ACROGENÆ.

*Filices—Ferns.	*Equisetaceæ—Horse-tails.
*Lycopodiaceæ—Club-mosses.	*Musci—Mosses.
*Marsileaceæ—Pillworts.	*Hepaticæ—Liverworts.

FILICES.—In this order the different parts of the plant spring from a *rhizome*, or root-stock; the elegant fronds or leaves being either separate and independent, or uniting by their stalks so as to form a sort of trunk, as in the tree-ferns. The fronds are furnished with forked veins, and are usually pinnatifid, and more or less compound; sometimes nearly simple and entire; in their vernation they are circinnate—that is, they unroll from the stem outwards in the form of a crosier. The reproductive organs appear on the mature plant in the form of *sori*, or brown membranous-looking spots, usually either upon the backs of the fronds, or on their margins. These sori either lie under a small shield-like *indusium*, or they are naked; or they are arranged along the margin of the leaf, which curls over them, and supplies the place of the indusium. Each sorus consists of a number of brownish bodies, called *thecæ*, or *sporangia*, each being in reality a case containing a number of minute *spores*, which are the true reproductive bodies. (For details of the development of these spores into plants, see VEGETABLE PHYSIOLOGY, page 75.)

The Ferns are divided into the following sub-orders: 1. POLYPODIACEÆ; sporangia in variously shaped sori on the back or margin of the frond, each having an elastic ring or rachis (vertical and incomplete, or horizontal and complete), by means of which the ripe sporangium is torn so as to set the contained spores free. 2. OSMUNDACEÆ; sporangia on a transformed contracted frond, with a terminal or dorsal ring more or less complete, reticulated, and opening vertically. 3. OPHIOGLOSSACEÆ; sporangia in spikes, sessile on a contracted frond, exannulate, two-valved (vernation of frond straight). 4. DANÆACEÆ; sporangia dorsal in masses, exannulate, splitting irregularly by a central cleft. The first sub-order is illustrated by the following genera: *Polypodium*, the polypody, which has naked sori; *Lastrea*, the shield-fern; *Cystopteris*, the bladder-fern; *Asplenium*, spleen-wort; *Pteris*, the common brake; *Athyrium*, to which belongs the lady-fern of our woods; *Adiantum*, maidenhair; and *Scolopendrium*, hart's-tongue, the frond of which is tongue-shaped and simple. The second sub-order is represented by *Osmunda*, the Royal fern; *Anemidictyon*, and *Lygodium*, the climbing-fern. The third sub-order contains *Botrychium*, the grape-fern or moon-wort; and *Ophiglossum*, the adder's-tongue; and the fourth sub-order, a few exotic genera. The Filices are widely distributed, delighting in humid soil and shady situations—some growing on trees.

Tree-fern.

The fronds of the family generally contain an astringent mucilage, and are thus considered as pectoral; the roots of some have recently been used successfully as anthelmintics and purgatives; and *Aspidium fragrans* has been employed as a substitute for tea. The young leaves and rhizomes of some New Zealand species are edible; and the fronds of the common brake, when burned, yield a considerable quantity of alkali.

Lycopodiaceæ (Club-mosses), *Equisetaceæ* (Horse-tails), and *Marsileaceæ* (Pillworts), are usually classed as FERN ALLIES. They display considerable variety of structure, and will well repay careful study.

MUSCI.—The Mosses present many points of interest. They are minute plants, with erect or creeping stems and small leaves, all their tissues cellular. At certain seasons, little flower-like heads are produced, some containing antheridia (so named from their resemblance to anthers), and others less conspicuous, consisting of pistillidia, which represent the female parts. At maturity, each antheridium opens at the apex, and emits a granular gelatinous mass; this consists of minute spermatozoa, which find their way into, and impregnate the pistillidia, and thus give rise to the development of the latter into an urn-shaped theca or spore-case, containing spores capable of germinating into new plants.

Mosses grow usually in shady situations, and are abundant in moist, temperate countries. They are divided into three sub-orders—Andreæaceæ, Sphagnaceæ, and Bryaceæ. The first is illustrated by the split-mosses (*Andreæa*), which are common on the Scottish hills; of the second, *Sphagnum*, bog-mosses is the only genus; while the third embraces the genera *Bryum* and *Hypnum*, and most other British mosses.

§ 2. THALLOGENÆ.

The orders under the Thallogenous sub-class of Cryptogams are:

*Lichenes—Lichens.	*Algæ—Sea-weeds.
*Fungi—Mushrooms.	*Characeæ—Charas.

LICHENES.—Lichens form not the least interesting section of the Cryptogamia, and their value on the score of utility is by no means unimportant. They are familiar objects to all in the form of apparent discolorations and incrustations on old walls and rocks; but some of them hang in festoons from the branches of trees (*Usnea*, *Alectoria*), while others (*Peltidea*) spread their thalli among mosses and herbage in shaded situations. They grow slowly, and attain an extreme age, as some of those growing on the primitive rocks of our highest mountain-ranges must be. 'The hoary Usneas, Ramalinas, and Physcias, like the gray beard of an old man, silently but eloquently proclaim time's ravages, and illustrate the constant succession of life upon death, growth upon decay, which is going on around us.' In their reproductive organs, they approach the Fungi, but are well distinguished by the presence

in their tissue of gonidia containing chlorophyl, which are capable of originating new plants.

The Lichens yield valuable dyes. Orchil, a red dye, supposed to have supplied the purple of ancient Tyre, is produced by *Roccella tinctoria*, a Southern European species which was discovered in the Cumbray Islands, in the west of Scotland, by Professor Balfour in 1855. *Cladonia rangiferina* is the Reindeer Moss, an important forage-plant in Lapland. Species of *Gyrophora* (*Tripe de Roche*) are edible, and furnished Franklin and his companions with food for many weeks in arctic regions. *Cetraria islandica*, the Iceland moss, contains starch and a bitter principle. *Lecanora tartarea*, the rock-moss, supplies the cudbear dye; and *Parmelia parietina* yields a yellow dye.

FUNGI.—The Fungi, or Mushroom family, which are among the lowest forms of vegetation, are extremely diversified in their size, shape, colour, and consistence. The common field-mushroom is one of the best known, and may be cited as a type of the family; but the puff-ball, truffle, moril, as well as the mould on cheese and stale bread, the mildew on trees, the rust on corn, the substance called dry-rot, and many other minute appearances of a similar nature, are all fungi. In the field-mushroom (*Agaricus campestris*), the plant consists first of some filamentous filaments or spawn, which look like roots, then the stipe or stalk, surmounted by the pileus or cup. 'When the mushroom first appears, the stalk is covered by a thin membrane, called the veil, which unites the cup to the lower part; but as the mushroom grows, this veil is rent asunder, and it either entirely disappears, or only a small portion of it remains round the stalk, which is called the *annulus* or ring. Under the cup are gills or lamellæ, which are of a dark reddish brown; and attached to these are the thecæ, containing the spores.' Many—as the moulds, &c.—are mere microscopic jointed filaments, or filaments surmounted by little ball-like receptacles which contain the sporules, or are mere spherical or filamentous cells, which increase with astonishing rapidity, each cell containing a number of undeveloped ones.

Among the more familiar genera are—*Agaricus*, the mushroom; *Tuber*, the truffle; *Morchella*, the morel; *Lycoperdon*, the puff-ball; *Puccinia*, the mildew; *Clavaria*, the yellow meadow fungus; *Podisoma*, the jelly-looking masses often found on juniper and savin bushes; and *Tubercularia*, the small, red, pimple-like fungus found on rotten sticks and trunks of trees. The Fungi are scattered everywhere—springing from the ground, yet without roots; under the ground, as the truffle; on all decaying organic substances; and even on living animals. What is called yeast is a spherical-celled fungus, having a nucleated development.

The plants of this order are not more diversified in form than in properties. Some are wholesome and palatable—as the mushroom, moril, truffle, &c.; others, similar to these in appearance, are deadly poisons. Many of the minuter fungi—as moulds, smuts, rusts, &c.—are noxious to the human system. Ergot forms a powerful and dangerous medicine. German tinder is prepared from a species of puff-ball, which, after being dried, is impregnated with nitre. The Siberian fungus (*Amanita*) is used to induce intoxication. The vinegar plant is one of the most singular forms of fungi; it is an abnormal state of *Penicillium glaucum* developed in saccharine fluid, which it has the property of converting into vinegar suited for table use.

ALGÆ.—The Algæ form a highly interesting family of plants, and are specially important to the physiologist, for it is in these that the phenomena of growth and reproduction are most successfully studied. This order—which has been wisely split up into *several orders*, concerning which our space will not permit of full details—embraces the very simplest forms of vegetation, as well as many having a complicated structure. The Algæ are not confined to the sea; many occur in fresh water and on the dry land. They are classified as follows: 1. MELANOSPERMEÆ or FUCACEÆ; brown-coloured sea-weeds. 2. RHODOSPERMEÆ or CERAMINACEÆ; rose-coloured sea-weeds. 3. CHLOROSPERMEÆ or CONFERVACEÆ; green-coloured sea and fresh-water weeds. 4. DIATOMACEÆ, Brittleworts; unicellular, in the form of frustules, usually coated with silica, and containing brown, rarely green, contents. 5. DESMIDIEÆ; unicellular, without silica, containing always green cell-contents. The first contains many of our large species of common sea-weeds; the second, those beautiful kinds so highly prized for albums; the third, those green filamentous species so common in stagnant waters, some of which fill up lakes with their interlaced masses of filaments; the fourth, those minute silicious bodies found in such amazing quantities in all parts of the world; and the fifth, the analogous non-silicious species, which display perhaps the most beautifully symmetrical forms of the vegetable kingdom.

Such, according to our limits, is an outline of the Natural System of Botany; which, though as yet not fully developed, is more interesting and instructive than any artificial method, however elaborate and complete. Undeveloped as we must admit it to be, harsh and difficult as much of its nomenclature is, unnecessarily multiplied and complicated as its orders and tribes really have been, it has still the germs of truth and nature within it, and only requires a cordial and patient elaboration, on the simple principles of its great founder, to render it what it professes to be—an exposition of the system upon which Nature has proceeded in the creation of the Vegetable Kingdom. Our brief synopsis can at most but convey a very general notion of vegetable life and relationship, and only introduce the student to the technical phraseology and mode of procedure: for further acquaintance with the subject, we cannot refer to more accessible sources than the excellent works published by Professor Asa Gray, Professor Lindley, and Professor Balfour.

HUMAN PHYSIOLOGY.

HUMAN PHYSIOLOGY is the science which treats of the functions of the body and the manner in which these are performed. By a function we mean the action performed by any part of the body. For example, one of the functions of the liver is to secrete bile, while that of the stomach is to digest food. It is the object of the present paper to describe as briefly as is compatible with clearness the most important of these functions. The functions of the human body may be conveniently classified into three great divisions: 1. The Function of Nutrition, or the nourishment of every part of the body, so as to enable each part to perform its special function; 2. The Function of Innervation, or the actions performed by the nerves, spinal cord, and brain; and 3. The Function of Reproduction, or the perpetuation of the species by offspring.

I. THE FUNCTION OF NUTRITION.

This function is a complex process. To keep up the integrity and vigour of the body, food must be procured, chewed or masticated, mixed with saliva, swallowed, digested in the stomach, the nutritious material absorbed by special organs in the bowels, called *villi*, and from them carried to various glands, where it is elaborated into blood. The blood is then conveyed through the body, giving up to the tissues what they require for nourishment, and carrying away materials resulting from their decay. Thus rendered impure, the blood must have the noxious materials removed. For this purpose, several organs, such as the lungs, the liver, the skin, the kidneys, and the lower bowel, are set apart. Thus the blood is constantly replenished with nutritious matters, and constantly being purified, so as to fit it for supplying each individual particle or cell of the body with exactly the material it requires. Bone requires earthy salts, muscle requires albumen, the nervous system requires fat, and so on.

The process of nutrition is complex only in the higher animals. In the amœba, a little animal which is nothing more than a mass of jelly-like living material, we find no trace of organs, and nutrition is carried on by any part of the body. But as we ascend in the scale of animal life, one organ after another is added, such as a digestive sac, glands for secretions to act on the food, a special fluid—the blood, an organ and vessels for circulating this fluid; and so on, till we come to the higher animals, where we find great differences in parts, and corresponding differences in function. We will divide nutrition into the following thirteen stages, namely:

1. FOOD, OR ALIMENT.

A living being is always in a state of change. His skin gives off water, either in the form of sweat, or as invisible vapour; his kidneys act similarly, the water in both cases containing salts and other matters in solution; and his lungs are always exhaling, not only watery vapour, but the gas known as carbonic acid, as may be readily shewn by breathing into lime-water, which soon assumes a milky appearance, in consequence of the formation of carbonate of lime. Moreover, the body, which has an almost constant temperature of about 98·4° F. is always giving off heat. The production of heat indicates chemical changes in the body, accompanied by waste of material. If this condition of things were to go on indefinitely, the weight of the body would gradually diminish. To retain the body in its normal state, we must therefore supply it with three things—*atmospheric air*, *water*, and *food*. We have placed them in the order of their importance.

Various classifications of the food of man have been proposed; but the following is simple and practical: (1) the *aqueous*, (2) the *albuminous*, (3) the *fatty*, *oily*, or *oleaginous*, (4) the *saccharine*, (5) the *gelatinous*, and (6) the *saline* groups. All our daily food is referable to one or more of these classes. The *aqueous* group includes not only water, but all fluids (except oils) used as drink, and it must be recollected that all our so-called solid foods contain a large percentage of water. The *albuminous* group (often termed the protein) is typified by the white of egg, and includes the gluten of flour, the chief constituents of flesh and cheese. These substances contain the four elements, carbon, hydrogen, oxygen, and nitrogen, and also a little sulphur or phosphorus, or both. The albuminous foods chiefly nourish the muscles, but they contribute, along with fat or oil, to almost every tissue. The *fatty* group includes all animal and vegetable fats or oils. They are composed of carbon (ranging from 60 to 80 per cent.), hydrogen, and a little oxygen. The *saccharine* (often termed the starchy or amyloid) group contains all the varieties of sugar, starch, dextrine, and gum; like the preceding group, they are composed solely of carbon, hydrogen, and oxygen. Both the fats and sugars belong to the group termed by chemists *hydrocarbons*, because they contain carbon or charcoal, and oxygen and hydrogen, in the proportions, or nearly in the proportions, necessary to form water. They contribute chiefly to the adipose or fatty tissue of the body. The *gelatinous* group is represented by cow-heel, isinglass, and such-like substances, yielding jellies and soups that stiffen on cooling; while the *saline* group includes mineral matters, especially common salt, and phosphates of the alkalies, and of lime, &c. The saline or mineral matters form bone, tooth, &c. and they are found in variable proportions in almost every fluid and solid in the body. It must be remembered, however, that a mixture of all of these constituents of food is essential to the formation of a nutritious diet, and, moreover, that there must always be a certain amount of sapidity or flavour in the food. We should

turn with disgust from a mess consisting of these constituents, even in proper proportions, if it were not properly cooked. The best example of a natural food is milk. It contains water, albumen in the form of caseine or cheese, fat in the form of butter, sugar, and various salts. Hence it is nature's food for all young animals of the mammalian group.

A daily amount of food varying from 33 to 35 ounces of dry food is sufficient to maintain the health of an adult man, not engaged in active labour, and of this a fourth or fifth part should be animal food; but in special cases much more or less may be taken with advantage. The arrangement and form of the teeth in man indicate that he should live on a mixed diet of animal and vegetable food; though, no doubt, there are examples on record of individuals who have lived in good health for many years entirely on either animal or vegetable food. By mixing these in proper portions, we are nourished on a smaller bulk of food than if we lived on either one or the other.

2. MASTICATION.

Mastication is effected in the cavity of the mouth by means of the teeth, which fit into sockets in the upper and lower jaw-bones. The upper jaw is immovable, or only movable with the entire head; but the lower jaw, with its teeth, is capable of moving upwards, downwards, backwards, forwards, and laterally, by means of the powerful muscles of mastication. It is by the varied movements of the lower teeth against the upper, through the action of these muscles, that food is broken down or masticated. In the adult there are 32 teeth, 16 in each jaw, and 8 on each side. There are from before backwards, beginning in the middle line of the jaw, 2 incisors or cutting teeth on each side; 1 canine or eye-tooth, for seizing; 2 premolars or bicuspids, for tearing; and 3 molars or grinders, for crushing and breaking up the food. The body and greater bulk of each tooth consists of a substance called *dentine*, composed of branching tubes; the top or crown is covered by a cap of *enamel*, a very hard substance, made of small hexagonal prisms; and the fang or root is protected by a layer of a material resembling bone, called *crusta petrosa*, or cement. In the centre of each tooth there is a cavity containing a pulpy matter, in which are nerves and blood-vessels.

3. INSALIVATION.

Insalivation is effected by the admixture of the secretions of the three pairs of salivary glands (the parotids, the sub-maxillaries, and the sub-linguals), and of the mucus secreted by numerous small glands beneath the lining of the cheeks, gums, and tongue, called *buccal* glands, with the triturated food. The common saliva formed by the combined secretion of these various secreting organs, is a colourless, slightly turbid, viscid, inodorous, and tasteless fluid. In the normal state, its reaction is alkaline. Saliva does not contain more than five or six parts of solid constituents to 995 or 994 parts of water. The daily quantity of saliva secreted by an adult man is estimated at about 48 ounces, but the activity of the salivary glands is dependent upon various influences and conditions. Thus, movement of the lower jaw, as in masticating, speaking, or singing, increases the secretion — acrid and aromatic substances and hard dry food also increase it. It is also under the influence of mental emotions and desires, through the nervous system, for the sight of a feast or tempting dish may make one's 'mouth water.'

The uses of the saliva in reference to digestion are partly mechanical and partly chemical. The chemical use of the saliva is to convert the starchy portions of the food into grape-sugar, and thus to promote its absorption. It also assists in speech and swallowing. The public speaker cannot articulate when his mouth becomes dry, and we cannot swallow a perfectly dry powder.

4. DEGLUTITION.

Deglutition is the act by which the food is transferred from the mouth to the stomach. The mouth leads into a cavity called the pharynx. Between it and the mouth is the pendulous or soft palate, which is a movable muscular partition that separates the two cavities during mastication. As soon, however, as the latter act is accomplished,

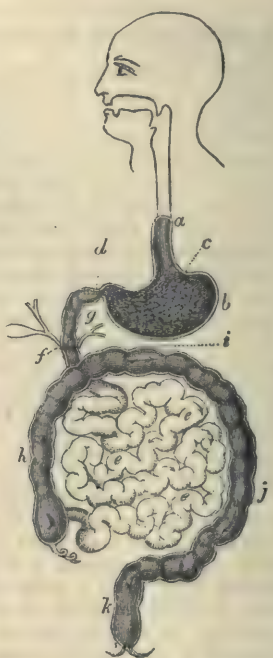


Fig. 1.—Human Alimentary Canal:

a, œsophagus; *b*, stomach; *c*, cardiac orifice; *d*, pylorus; *e*, small intestine; *f*, biliary duct; *g*, pancreatic duct; *h*, ascending colon; *i*, transverse colon; *j*, descending colon; *k*, rectum.

and the bolus is pressed backwards by the tongue, the soft palate is drawn upwards and backwards, so as to prevent the food passing into the nose. The opening of the windpipe is closed by a lid called the epiglottis. The bolus or pellet of food having arrived near the œsophagus or gullet (which is continuous inferiorly and posteriorly

with the pharynx), is driven into it by the action of certain muscles, which almost surround the pharynx, and are termed its constrictor muscles. All voluntary action ceases as soon as the food is pressed backwards by the tongue into the pharynx. It is impossible to recall the pellet, and it is necessarily carried on (without even our cognisance) into the stomach. This involuntary mechanism is called a *reflex* action. All reflex actions require a stimulus to call the parts into action. The stimulus in this case is the contact of the food with the back of the tongue and throat. It will be found on experiment that the reader cannot perform the action of swallowing if nothing, not even saliva, is in his mouth.

5. DIGESTION IN THE STOMACH.

The whole of the alimentary canal below the diaphragm, or muscular partition which separates the cavity of the chest from that of the abdomen or belly, possesses the following points in common, in relation to structure. The stomach, the small intestine, and the large intestine, are all lined by mucous membrane, have a muscular coat consisting of two sets of distinct fibres—namely, circular fibres which surround the tube or viscus after the manner of a series of rings, and longitudinal fibres running in the same direction as the intestine itself—and are invested with a smooth, glossy, serous membrane, which, while it retains the viscera in their proper position, also permits their necessary movement with a minimum of friction.

The human stomach is an elongated curved pouch, lying immediately below the diaphragm. It is very dilatable and contractile, and its function is to retain the food until it is duly acted upon and dissolved by the gastric juice, which is secreted by glands lying in its inner coat, and then to transmit it, in a semi-fluid state, into the first part of the small intestine, called the duodenum. Its average capacity is about five pints.

The mucous membrane, or lining coat of the stomach, is thick and soft, and lies in irregular folds, in consequence of the contraction of the muscular coat, unless when the organ is distended with food. On opening the stomach, and stretching it so as to remove the appearance of folds, we perceive numerous very shallow pits or depressions. The rest of the thickness is chiefly made up of minute tubes, running vertically towards the surface of the stomach, and secreting the gastric juice from the blood in the capillaries or minute blood-vessels which abound in the mucous membrane. These tubes are lined half-way down with epithelial cells, and the bottom is during digestion filled with molecular matter and a few cells. Other tubular glands are also found in the stomach, which are believed to secrete mucus.

When food is introduced into the stomach, it is subjected to three actions—first, to heat, the temperature of the stomach being, during digestion, about 99° F.); second, to a slow movement round and round, so as to bring the food into contact with the lining; and, third, to the chemical action of a special fluid—the gastric juice.

The food on entering the stomach first passes into the cardiac end, thence along the greater curvature from left to right to the pyloric end, and from thence along the lesser curvature from right to left.

The changes in the mucous membrane are—The inner surface of the healthy fasting stomach is of a paler pink than after the introduction of food, which causes the exudation of a pure, colourless, viscid fluid, having a well-marked acid reaction. This fluid, which is the gastric juice, collects in drops, which trickle down the walls, and mix with the food. Its two essential elements are—1. A free acid, which in some cases seems to be hydrochloric alone, and in others a mixture of hydrochloric and lactic acids; and 2. An organic matter called pepsine, which is highly nitrogenous, and allied to the albuminates.

The uses of this fluid are not only to dissolve but also to modify the nitrogenous elements of the food (such as albumen, fibrine, caseine, and, in short, all animal food except fat, and the albuminous principles of vegetable food), converting them into new substances, termed *peptones*, which, although they coincide in their chemical composition, and in many of their physical properties, with the substances from which they are derived, differ essentially from them in their more ready solubility in water, and in various chemical relations.

The gastric juice exerts no action on the fats and the carbon-hydrates (sugar, starch). If the fats or starches are in cells, the walls of which are formed of albumen, the walls are dissolved, and the contents set free.

The process of gastric digestion is slow. According to Beaumont's researches on Alexis St Martin, a man who had an injury which left a permanent opening into his stomach, guarded by a little valve of mucous membrane, the mean time required for the digestion of ordinary animal food, such as butcher-meat, fowl, and game, was from two hours and three-quarters to four hours.

What becomes of the matters that are thoroughly dissolved in the stomach? The albuminates, &c. which are converted into peptones, are for the most part taken up by the blood-vessels, and by another set of vessels called the lacteals. The rapidity with which aqueous solutions of iodine of potassium, the alkaline carbonates, lactates, citrates, &c. pass into the blood, and thence into the urine, saliva, &c. shews that the absorption of fluids must take place very shortly after they are swallowed; and there is little doubt that the blood-vessels (capillaries) of the stomach constitute the principal channel through which they pass out of the intestinal tract into the blood.

There can be no doubt that the stomach is admirably adapted for the digestion of the food introduced into it, because it has been shewn by numerous experiments that digestion will go on in gastric juice out of the stomach, but that it requires three or four times longer a period than when performed by the stomach itself. In the stomach, in most individuals, rice and tripe are digested in one hour; eggs, salmon, and venison in one and a half hours; tapioca, liver, fish, in two hours; lamb, pork, and turkey in two and a half hours; beef, mutton, and fowl, three and a half hours; and veal in four hours. There are, however, considerable differences in various individuals, or even in the same individual at different times.

6. DIGESTION IN THE BOWELS.

After the food, by digestion in the stomach, has been converted into a semi-fluid mass called the chyme (*chymos*, juice), it passes into the intestine. The length of the human intestine is usually about twenty-five feet. As a general rule it may be stated that the intestines of herbivora are much longer than those of carnivora. This is due to the nature of the food. In those animals, such as the ox, which live on a food very different, physically and chemically, from the tissues of the individual, a complicated digestive apparatus and a long intestinal tube will be found; whereas those which live on food readily converted into their own tissues (such as a weasel, which preys on the blood of other animals), have a simple digestive apparatus and a short tube.

The human intestine consists of a convoluted tube, which, from a great change in calibre in two different parts, is divided into (1) the small intestine, and (2) the great intestine. The small intestine is about twenty feet in length, and is divided by anatomists into three portions—the *duodenum*, *jejunum*, and *ileum*, the latter opening into the great intestine. The whole of this tube is connected with the back of the abdominal cavity by a thin web, called the *mesentery*, on which blood-vessels, nerves, and absorptive vessels called lacteals, ramify before penetrating and supplying the bowel. When the small intestine is slit open, it presents a large number of transverse folds, which are simply doublings of the mucous membrane, so as in little space to increase the surface for absorption. It has also a peculiar velvety appearance, which is due to the fact that it is covered over by innumerable small projections termed *villi*. They are more numerous in the upper than in the lower portions of the bowel. When examined by the microscope, they are found to be prolongations of the mucous membrane, shaped like the finger of a glove, and each is covered by a layer of epithelial cells. In the centre we find the commencement of the true absorbent vessel, called a *lacteal*, and surrounding it a network of vessels of very minute size. The villi in the small intestine are to a certain extent comparable to the delicate rootlets of a plant. The latter absorb moisture and soluble nutriment from the soil, while the former are bathed in a nutritious fluid, the chyme, and absorb readily fluids by the blood-vessels, and fatty matters by the lacteals. We find also scattered in large numbers over the mucous membrane, minute tubular glands called *Lieberkühnian glands*, after the anatomist Lieberkühn, who first described them. In the upper part of the duodenum, there are a few glands, like small clusters of grapes, called Brunner's glands, the function of which is unknown.

The great intestine, about five or six feet in length, is so termed because it is so much wider than the smaller one. It is also divided into three parts: the *cæcum*, which is a wide pouch, often of great size in herbivorous animals, and into which the small intestine opens, the entrance being guarded by a valve; the *colon*, which forms the greater part of the large intestine; and the *rectum*, which is situated entirely in the pelvis, and terminates in the anus. The great resembles the small intestine in general respects.

There is abundant evidence that the function of the villi is connected with absorption, and mainly with the absorption of fatty matters. 1. The villi exist only in the small intestine where the absorption of food goes on. 2. They are turgid, enlarged, and opaque during the process of digestion and absorption, and small and shrunken in animals that have been kept fasting for some time before death.

The function of the muscular coats is to propel the food along the bowel. This they perform by alternate contractions and relaxations, and thus a wave-like motion is produced. This motion may be readily seen in the intestines of an animal recently killed, and is termed a peristaltic action.

When the food, reduced to a pulpy mass in the stomach, termed chyme, passes into the duodenum, it is mixed with three fluids: 1, the bile; 2, the pancreatic juice; and 3, the intestinal juice.

The *bile* is an alkaline fluid secreted by the liver, and, after having been collected in the gall-bladder, finds its way into the upper part of the small intestine by a duct, which usually unites with that of the pancreas, and opens by a common orifice. As it flows from the liver, the bile is a thin greenish-yellow fluid, sometimes olive-brown; but when acted on by the gastric juice, it acquires a distinctly yellow or green hue, hence the appearance of vomited bile. Its main use seems to be to promote the digestion of fatty matters, and it accomplishes this end by a peculiar physical action both on the fats and on the intestinal walls, disintegrating the former, and impressing on the latter (by moistening the villi) a peculiar condition which facilitates the absorption of fatty matters. The bile separates nutritious matters from those which are non-nutritious, while it stimulates the muscular movements of the bowels and arrests putrefaction in the fæces.

The *pancreatic juice* is secreted by a long, narrow, flattened gland called the pancreas, or sweetbread, which lies deeply in the cavity of the abdomen, immediately behind the stomach. It is a lobulated or racemose gland, consisting of an immense number of small pouches grouped round the extremities of small ducts. These ducts unite with others, becoming larger and larger, until the great duct of the gland is formed.

The secretion is a colourless, clear, somewhat viscid, and ropy fluid, devoid of any special odour, and exhibiting an alkaline reaction. It contains a peculiar principle called pancreatine.

The function of the pancreatic juice is to emulsionise the fat of the chyme, and thus promote its absorption. If the duct of the pancreas be tied, and fat be taken as food, a large amount of it will appear in the fæces; and the same result has been seen in the human being in cases of diseased pancreas. The pancreatic juice also converts any starchy matter, which may have escaped the action of the saliva, into grape-sugar.

Of the last of the fluids poured into the intestine, the *intestinal juice*, we know little. It is the aggregate secretion of the various glands which occur in the walls of the smaller intestine. It is a colourless, or sometimes yellowish, ropy, viscid fluid, which is invariably alkaline. It seems to unite in itself the leading properties of the pancreatic and gastric juices; that is to say, it resembles the former in converting starch into

sugar, and the latter, in dissolving flesh and other albuminous bodies.

The line of demarcation between the small and large intestine is very obvious, and by the peculiar arrangement of the ileo-cæcal valve, which guards the entrance of the small into the great intestine, matters are allowed to pass forward with facility, while regurgitation is impossible. The contents of the large intestine differ very materially from those which are found in the small intestine, and constitute the fæces. They are more solid and homogeneous, and are often moulded into a definite shape. The only essential change which the contents undergo in this part of their course is, that they increase as they pass onward in solidity, in consequence of the absorption of fluid from them by the mucous membrane. They are propelled onwards into the rectum by the vermicular action which has been already described, and are at last expelled by a voluntary effort.

The fæces consist partly of undigested materials and partly of matters which are derived from the mucous membrane of the great intestine. It is in the great intestine the chyme first acquires a fæcal odour, which increases in intensity as the material passes along the bowel. This odour is not due simply to putrefaction, but to the presence of peculiar effete matters, which are thrown off by the lining membrane of the bowel.

7. ABSORPTION OF NUTRITIOUS MATTER.

As the chyme is propelled along the alimentary canal, the watery portion, holding various substances in solution, is absorbed by the blood-vessels, while the fatty matter is taken up by the lacteals. It is believed that this absorptive action is really a physical process dependent on osmotic action. The whole of the nutritive material thus separates itself into two parts: one which passes directly into the blood, and the other which enters the lacteals, and in these becomes a milky fluid called the *chyle*. It is important to remember that all the blood circulating in the digestive organs must pass through the liver before entering the general circulation, and from it the cells of the liver select and elaborate their secretions. But the chyle passes into the blood indirectly. It is first conveyed to numerous glands in the neighbourhood of the intestines, called mesenteric glands. Before entering these glands it is a milky fluid, essentially molecular; but after it has passed through the glands it is found to contain small, round, biconcave discs, termed chyle corpuscles, along with much molecular matter. The lacteal vessels proceeding from these glands unite with corresponding sets of vessels from the lower limbs, called lymphatics, in a wide cavity opposite the last dorsal vertebra, the *receptaculum chyli*. From this cavity a duct, the thoracic duct, ascends through the thorax, receives branches from the left arm and left side of the head, and unites with the venous system at the root of the neck on the left side, the point of junction being where the left internal jugular vein unites with the great vein of the left arm, the left subclavian. The lymphatics of the rest of the body unite to form the right lymphatic duct, which joins the venous system at a corresponding point on the opposite side. The whole of the chyle, therefore, passes into the blood at the root of the neck; from thence it goes through the right side of the heart to the lungs, where the corpuscles probably acquire colour, and become the coloured corpuscles of the blood.

8. SANGUIFICATION.

By this term we mean the making of blood. In the lowest animals, such as in the amœba, we find no circulating nutritious fluid. When we ascend higher in the scale we find a colourless fluid containing molecules moving in certain definite directions by the action of cilia in the general cavity of the body, as in a sea-anemone. Still higher we meet with a colourless fluid circulating in vessels, frequently communicating with the body-cavity, and propelled by a special contractile organ, as in the sea-urchin or ascidian; and at last we meet with a coloured fluid, circulating in vessels separate from the body-cavity, and having a propelling organ, or heart, of more or less complex structure, as in all the vertebrata. This fluid, in the higher animals and in man, is derived from three sources: 1st, from materials absorbed in the primary digestion of the food in the alimentary canal; 2d, from the secretions of certain glands called blood-glands, found in various parts of the body; and, 3d, from materials re-introduced into the blood from the tissues, which are products of the decomposition and solution of portions of these tissues consequent on their vital activity. The so-called blood-glands are—the spleen, a large organ found almost in juxtaposition with the left end of the stomach; the suprarenal capsules, two organs found in the lumbar region, one on the top of each kidney; the thymus, a gland found in the thorax, immediately behind the breast-bone, of larger size before birth and during the earlier years of life than during adult life; the thyroid, a gland existing in front of the box of the larynx; the pituitary and pineal glands, found in the brain; the glands of Peyer, in the mucous membrane of the small intestine; and lastly, the lymphatic glands, which we find in many parts of the body, such as in the groin, the armpit, the neck, &c. and which we readily recognise as hard 'kernels' during the inflammation of any adjoining part. All of these glands agree in certain points of their anatomy; they have no ducts to carry off the secretion, except we regard the numerous lymphatics by which they are supplied as such; they consist essentially of shut sacs, containing numerous molecules, nuclei from which cells may be developed, and fully formed cells resembling white blood corpuscles; and finally, they are richly supplied with blood-vessels, lymphatics, and nerves. That they are really connected with the formation of blood, more especially of the colourless corpuscles, is probable from the fact, that in a disease known as leucocythæmia, in which there is a great increase in these cells, we find also that one or more or all of the blood-glands are much enlarged.

9. THE BLOOD AND ITS CIRCULATION.

The blood is the most important and most abundant fluid in the body, and deserves the popular term of the 'vital fluid.' With the exception of a few tissues, such as the centre of the cornea of the eye, the nails, and the hair, it pervades every part of the body, as may be

shewn in the case of the skin by puncturing any part of it with a needle. The total quantity is estimated at about one-eighth of the weight of the body, or about 20 lbs. in a man of average size. Its colour is red, but it varies from a bright scarlet in the arteries to a dark purple in the veins. When, however, a minute drop is examined under the microscope, it is seen to be made up of, first, a clear colourless fluid; and, secondly, of a multitude of small solid bodies or corpuscles, which float in the plasma. This plasma, called liquor sanguinis, is composed of water richly charged with materials derived (through the chyme) from the food; namely, albumen, fibrine, various fats, &c. The greater part of the blood—about 70 per cent.—is made up of water. It contains a very small amount of fibrine, about 7 per cent. of albumen, 14 per cent. of corpuscles, and the remainder consists of extractive matters, fats, and various salts. The great majority of the corpuscles are of a yellowish-red colour, and by their enormous number seem to impart a red hue to the blood; while a few are white or colourless. The red corpuscles have a diameter of about $\frac{1}{3200}$th of an inch, being about $\frac{1}{4}$th of that fraction in thickness; and in form they are circular biconcave discs, and in freshly drawn blood they arrange themselves by contact of their flat surfaces into little rolls like piles of coins. The colourless corpuscles are larger, globular in form, and present a granulated appearance. Recently it has been shewn that these are little masses of living protoplasm, capable of spontaneous movement, and that they are identical with the corpuscles found in purulent matter or pus. In all classes of animals the colourless corpuscles are alike; but the form of the coloured corpuscles varies, being oval in fishes, reptiles, and birds. In all mammals they are circular, with the exception of the camels and llamas, where they are oval. Shortly after its removal from the body, the blood begins to thicken or coagulate, and soon separates into two distinct parts, one of them being a dark-red jelly or clot, which is the heavier of the two, and sinks; while the other is a clear straw-coloured fluid, called the serum, which covers the clot. This depends on the formation of a substance called fibrine, which forms a meshwork of fine molecular fibres, entangling the corpuscles. When a coagulum appears, fibrine is produced by the union of two substances present in solution, one called fibrinogen, and the other termed fibrino-plastic substance, the latter probably being a substance known as globulin, which forms a large part of the coloured corpuscles. This remarkable property of coagulation is the chief cause of the arrest of bleeding from a wound.

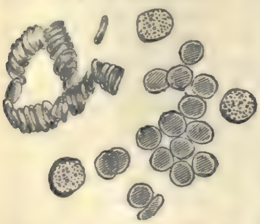


Fig. 2.—Blood Corpuscles highly magnified.

The blood is in constant motion in a definite direction during life, and the motion is known as the *circulation*. Its true course was discovered by Harvey, about 1620. The organs of circulation are the heart, arteries, veins, and capillaries. The course of the blood through these organs will be best elucidated by the aid of a diagram, which is equally applicable for all other mammals as well as for man and for birds. The shaded part of fig. 3 represents structures filled with impure or venous blood, while the unshaded portion represents structures in which pure oxygenated arterial blood occurs. In this diagram we observe a dotted circle, representing a closed bag or sac, termed the pericardium, and inclosing the four cavities *c*, *v*, *c'*, *v'*, of which the heart is composed. Two of these cavities, *c* and *c'*, are for the purpose of receiving the blood as it flows into the heart, and are termed the ***auricles;*** while the two cavities, *v* and *v'*, are for the purpose of propelling the blood through the lungs and general system respectively, and are termed the *ventricles*. The vessels that transport blood into the auricles are termed *veins;* and the vessels through which blood is driven onwards from the ventricles are known as *arteries*. The diagram further shews that what we commonly term the heart is in reality *two distinct hearts* in apposition with each other; one, shaded in the figure, which is called the right, or venous, or pulmonary heart; and the other, unshaded, which is called the left, or arterial, or systemic heart, the last name having been given to it because the blood is sent from it to the general system; just as the right heart is termed pulmonary from its sending blood to the lungs. We will now trace the course of the blood as indicated by the arrows in this diagram, commencing with the right auricle, *c*. The right auricle contracting upon the venous or impure blood which has been returned from the body, and with which we suppose it to be filled, drives its contents onwards into the right ventricle, *v*, through an opening between these two cavities, called the right auriculo-ventricular opening, which is guarded by a valve, named tricuspid, from its being composed of three pointed membranous expansions, which almost entirely prevents the regurgitation or reflux of the blood from the ventricle into the auricle. The ventricle, *v*, being now filled, contracts; and, as the blood cannot return into the auricle, it is driven along the shaded vessel, the dividing branches of which are indicated by *f*. This vessel is known as the pulmonary artery, and conveys the blood to the lungs. At its commencement it is guarded by valves, termed, from their shape, the semilunar pulmonary valves, which entirely prevent the blood which has once been propelled into the pulmonary artery from re-entering the ventricle. The pulmonary artery gradually divides into smaller and smaller branches, which ultimately merge into capillaries. In these capillaries, which are freely distributed over the external surface of all the air-cells (of which the lung is mainly composed), the venous blood is

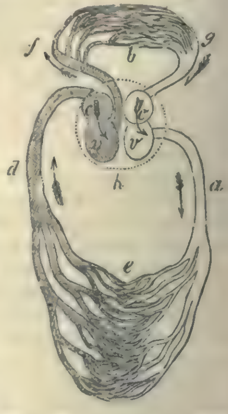


Fig. 3.—Mode of Circulation in Man and other Mammals, and in Birds: *h*, heart; *v*, right ventricle; *v'*, left ventricle; *c*, right auricle; *c'*, left auricle; *a*, aorta; *d*, vena cava; *e*, greater circulation; *b*, smaller circulation; *f*, pulmonary artery; *g*, pulmonary veins.

brought in contact with atmospheric air, gives off its carbonic acid gas (which is its principal impurity), and absorbs oxygen, by which processes it is converted into pure or arterial blood. The capillaries, *b*, in which the blood is arterialised, gradually unite to form minute veins, which, again, join to form larger vessels, until finally the blood is collected into four vessels, known as pulmonary veins (two from each lung), which pour their contents into the left auricle. Only one such vessel, *g*, is shewn in the figure, because the main object of this diagram is to illustrate the mode and general direction in which the blood circulates, not to indicate the special vessels through which it flows in different parts of the body. The blood, now fitted for the various purposes of nutrition, enters the left auricle, *c'*, which, by its contraction, propels it into the left ventricle, *v'*, through the left auriculo-ventricular opening. This opening, like the corresponding one in the right heart, is guarded by a valve, which, from its form, is termed the mitral valve, and which entirely prevents the reflux of the blood. The left ventricle, *v'*, contracts and drives its contents into the large artery, *a*, which represents the aorta—the great trunk—which, by means of its various branches (none of which are indicated in the diagram), supplies every portion of the body with pure arterial blood. From the aorta and its various subdividing branches the blood passes into the capillaries, *e*, which occur in every part of the system. In these capillaries it undergoes important changes, which may be considered as almost exactly the reverse of those which occur in the pulmonary capillaries; it parts with its oxygen, becomes charged with carbonic acid, and, as it leaves the capillaries and enters the minute veins formed by their union, presents all the characters of venous blood. The veins gradually unite till they form two large trunks, termed the superior and inferior *venæ cavæ*, which pour their contents into the right auricle—the point from which we started. Only one of these great veins, *d*, is indicated in the diagram. We thus perceive that there is a complete double circulation; that there is a lesser circulation effected by the blood in its passage from the right to the left heart through the lungs, and that there is a great circulation effected by that fluid in its passage from the left heart, through the system generally, to the right heart.

The heart is situated in very nearly the centre of the cavity of the chest. Its form is somewhat conical, the lower end tapering almost to a point, and directed rather forwards and to the left. This lower portion alone is movable, and, at each contraction of the heart, it is tilted forwards, and strikes against the walls of the chest between, in man, the fifth and sixth ribs, or a little below the left nipple. All the large vessels connected with the heart arise from its base, and serve, from their attachment to the neighbouring parts, to keep that portion of it fixed.

The substance of the heart is composed of a spiral arrangement of no less than seven layers of muscular fibre. When the ventricles contract, the blood is propelled from them, not in a direct manner, but with a sort of spiral motion, as if it were really wrung out of the heart.

But although the heart is the chief organ for propelling the blood, there are other forces at work. When the right ventricle contracts, blood is propelled into the aorta, which, however, contained blood at the time. This blood is pushed forwards, and the aorta dilates. When the propulsive power has ceased, the aorta, being a very elastic tube, recovers its original calibre. In doing so, it assists in forcing the blood onwards. Thus by successive portions of the larger arteries acting in the same manner, dilating with the impulse, and regaining their size by elasticity, the original mechanical force of the heart, which throws blood into the aorta in a series of successive jets, is converted into a uniform wave-like flow, which we term the pulse. The *pulse*, which beats about seventy times per minute, is the change produced in the diameter and length of an artery when it receives the wave of blood. The tissues also exert an attractive influence on the blood, drawing it forwards; and, consequently, we find that wherever we have activity of growth in any part of the body, there is a determination of blood to that part. We see this in the congestion which precedes the annual growth of a stag's horn. After the blood has passed through the capillaries and into the veins, the power of the heart has reached a minimum. The blood is now forced along the veins to the heart, chiefly by the pressure of the muscles. The veins are provided with valves, which are so arranged as to allow the blood to flow only towards the heart; and, consequently, when a muscle contracts and presses on a vein, the blood is propelled forwards. Thus muscular exercise assists occasionally in removing venous congestions. Lastly, the movements of respiration affect the circulation; inspiration, by increasing the flow of blood along the great vessels to the heart; while expiration has the contrary effect.

10. RESPIRATION.

The organs and process of respiration now claim our attention. We have already stated that the blood of the arteries differs in colour from that of the veins, the former being of a bright scarlet tint, while the latter is purplish in colour. The *arterial* represents pure, and the *venous* impure blood; the change from the former to the latter having taken place in the capillaries which form the bond of union between the termination of an artery and the beginning of a vein. The chemical differences between arterial and venous blood are slight, except in relation to the gases held in solution in these fluids. The two kinds of blood differ widely in this respect, there being a smaller quantity of oxygen, and a greater quantity of carbonic acid in venous than in arterial blood.

The organs by which the impure and dark venous blood is converted into pure, bright scarlet arterial blood, fit for nourishing the various tissues of the body, are the lungs, and the agent by which this change is effected is the oxygen of the air we breathe. In their simplest form, as they occur in certain reptiles, they are mere air-sacs, existing as two elastic membranous bags, having small honey-comb-like depressions on their inner surface, communicating with the external air by a tube known as the windpipe, or *trachea*, which opens through the larynx or organ of voice into the throat. These bags are lined by a delicate, thin, and moist

mucous membrane, in which is imbedded a network of capillaries, through which all the blood is in turn driven by the heart. The moist partition between the blood in this network and the air in the interior of the lungs, is so thin as to allow an interchange between the gases of the blood and the gases of the air; that is to say, oxygen passes from the air in the air-cells into the blood, while carbonic acid gas and aqueous vapour pass outwards from the lungs into the air in the air-cells. This is a purely physical phenomenon, dependent on the laws of diffusion and admixture of gases through animal membranes.

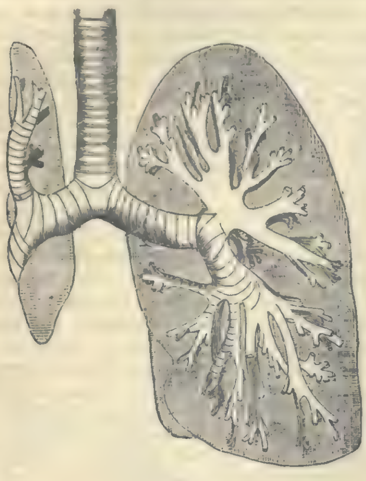


Fig. 4.

In the higher animals and in man, these essential parts are much complicated and modified in a variety of ways. The anatomical details may be considered under the following heads. *Firstly*, the lungs must afford by their internal arrangement an immense extent of internal mucous membrane, covered by vascular network, through which, as in the simpler form, the blood flows in innumerable minute streamlets, only separated by an extremely thin membrane from the atmospheric air that has been inhaled; *secondly*, there must be such an arrangement of the circulating system, that fresh blood may be perpetually driven from the right side of the heart through the lungs, and onward to the left side of the heart; and *thirdly*, there must be arrangements for the frequent and regular change of the air contained in the lungs.

We shall first consider the lungs and the passages leading to them. The back of the mouth or pharynx is connected with the outer air in two ways—namely, by the nasal passages and nostrils, and by the mouth. Through either of these channels, the air may pass to and from the lungs, but the nostrils are, properly speaking, the entrances to the respiratory system. Behind the root of the tongue, we find a chink or aperture, the *glottis*, bounded laterally by two folds of membrane called the *vocal chords*, which may be more or less widely separated from each other. This chink or aperture is guarded by a leaf-like lid, the *epiglottis*, which can be closed when expedient, so as to prevent the entrance of particles of food, drink, &c. The glottis opens downwards, into a box-like chamber called the *larynx* (which is the organ of voice), and leading downwards from the larynx runs the *trachea*, or windpipe, which is kept permanently open for the passage of air, by cartilaginous rings, that surround the anterior two-thirds of it. These are united, and the back of the tube is formed by a fibrous membrane or muscle. The windpipe, which is easily felt by the hand, and lies just below the projecting part of the larynx, popularly known as Adam's Apple, is about four and a half inches in length, and about three-fourths of an inch wide. Passing into the cavity of the chest, it divides into two branches, which are termed the right and left *bronchi*. Each bronchus enters the lung of its own side, and divides into a great number of smaller tubes, called the *bronchial tubes*, which again go on subdividing. These finest tubes end in elongated dilatations, averaging $\frac{1}{70}$th of an inch in diameter, which are called the *air-cells*. If we can conceive a bunch of grapes with its stem and all its minute branches, and the grapes attached to the ends of them to be hollow, we get a good idea of the mode in which the lung is constructed, except that it does not represent all the sacculation or partitioning of the terminal cells. It is in consequence of the air included in these cells that the lungs have their soft spongy feeling, and crackle when compressed between the fingers. Each lung is invested by its own investing serous membrane, termed the *pleura*, which serves the double purpose of facilitating the movements necessary in the act of respiration, and in suspending each lung in its proper position.

The blood is being perpetually changed and driven in a constant current through the lungs by the action of the heart, the venous or impure blood being collected in the right ventricle, and thence conveyed by the pulmonary artery into the lungs. In these, again, it gives off carbonic acid and aqueous vapour, and absorbs oxygen (as already described); and after these changes, it is collected, and returned to the left auricle by four vessels called the pulmonary veins.

The mode in which the air is renewed in the lungs next requires notice. This is effected by the respiratory movements, which consist in alternate acts of inspiration and expiration, with an intervening pause before the process is renewed. An adult man in a sitting position performs the respiratory act from thirteen to fifteen times in the minute, but much more rapidly if taking exercise. At each inspiration, about 30 cubic inches of air are inspired, and at each expiration nearly the same volume is exhaled, difference being allowed for temperature, which in the exhaled air may equal that of the blood. From 300 to 400 cubic feet of air thus pass through the lungs of a man at rest in the course of twenty-four hours, and these are charged with carbonic acid, and deprived of oxygen to the extent of nearly 5 per cent.; or, to put it in another form, about 18 cubic feet of the one gas are taken in, and of the other gas are given off. The quantity of carbon thus excreted in the form of carbonic acid gas is nearly represented by eight ounces of pure charcoal. The amount of watery vapour separated by the lungs varies from six to twenty ounces daily, according to the

diet, exercise, temperature, humidity of the air, &c.

The mechanical means by which these changes are effected are partly to be sought for in the elasticity of the lungs themselves, and partly in the mobility of the sides and bottom of the cavity of the chest, which is thus enabled to alter its size with each respiratory act. The sides of the chest are mainly formed by the ribs, which are so attached to the spine as to be freely movable upwards and downwards by two sets of intercostal muscles. Again, the *diaphragm*, the great muscular partition between the chest and the belly, is always convex to the former; but when it contracts, the convexity is lessened, and consequently the capacity of the chest is increased.

A knowledge of the respiratory process explains the great benefit to be derived from efficient ventilation. Ten thousand parts of ordinary atmospheric air contain from 2 to 4 parts of carbonic acid. If this gas be present to the extent of $1\frac{1}{2}$ to 3 parts in 1000, headache and giddiness are felt; and if it be increased to 20 parts in 1000, death will in all likelihood be the result. To secure a proper degree of dilution of carbonic acid in a small room, so as to render the air fit for respiration, about 2000 cubic feet of fresh air should be introduced every hour.

11. THE NOURISHMENT OF THE TISSUES.

The various tissues of the body, such as muscle, bone, nerve, or brain, are nourished by the blood. But as this fluid is almost the same in chemical composition in different parts of the body, and as the tissues differ much in this respect from each other, we must adopt the theory that each tissue has an elective power in itself, whereby it selects from the blood exactly the material it requires for its growth. To secure healthy nutrition, we must have an adequate supply of blood. If any part of the body is not supplied with abundance of blood, its actions are enfeebled; and if the supply be cut off altogether, it soon weakens and dies. The blood must also be healthy in quality. If affected by disease of any organ, so that certain injurious materials are not eliminated, the general nutrition of the body speedily suffers. To secure proper nutrition, a part must, thirdly, be subject to the influence of the nervous system. Disease of the spinal cord causes paralysis of the lower limbs, and the muscles become soft, flabby, and diminish in size. Section of a nerve supplying a part is often followed by destruction of the part by ulceration. Finally, the part itself must be in a healthy condition to secure proper growth. Any tissue which has acquired any peculiarity of structure by previous disease, retains this peculiarity for many years; but in course of time the tissue tends to revert to its original condition. This explains such phenomena as the perpetuation of cicatrices, and the influence of the vaccine virus. In the latter case, the virus stamps a peculiar quality on the blood and tissues, which modifies any subsequent attack of small-pox. Growth is dependent essentially on the supply of material to the tissues by the blood, and on the amount of waste of tissue. If the supply exceeds the waste, as in childhood, the body increases in weight and power; if the supply and waste are equal, the body may remain in a stationary condition for many years, as in middle life; and if the supply is much less than the waste, the body loses weight and strength, as in old age.

12. SECRETION.

Secretion is that function by means of which certain fluids are separated from the blood for further service in the economy. Various of these secretions, such as the saliva, gastric juice, pancreatic juice, &c. have been already described, but here we may briefly refer to the process of secretion generally. However complicated the structure of the various secreting glands may be, it is found, on minute examination, to consist of a delicate membrane, called a basement membrane, having blood-vessels richly distributed under its attached surface, and actively growing cells on its free surface. By foldings and reduplications of these elements of structure, all secreting glands are formed. The cells, however, are the active agents. They select from the blood the materials necessary, and form the secretion. Recent researches have shewn that these cells are directly influenced by the nervous system. The secretion is found in their interior. They are developed, grow, live a certain time, drop off from the membrane, and, becoming ruptured, the secretion is set free. Thus secretion is not opposed to growth, as at one time supposed: it is dependent on the growth of certain cells.

13. EXCRETION.

During the vital activity of the tissues, new particles are assimilated by the process of growth already described. On the other hand, certain materials are worn out, and becoming soluble, pass into the blood. These effete matters must be removed from the blood, and cast out of the body, so that this important fluid may be kept in a healthy condition. This process of removal is the function of excretion. There are five great channels of excretion:

1. *The Lungs.*—The lungs, as already described under Respiration, separate from the blood carbonic acid and watery vapour.

2. *The Liver.*—This organ is the largest and heaviest gland in the body, weighing, on an average, 65 oz. avoirdupois. It is situated on the right side, beneath the lower ribs. It consists of five lobes, of a dark reddish colour, and these lobes are divided into lobules. The lobules are bound together by areolar tissue, and their structure is similar. The liver is supplied with the blood from which it derives its secretions by the portal vein, a vessel which collects all the blood circulating in the stomach, spleen, and intestines. The portal vein divides and subdivides in the liver, till it forms a plexus of minute vessels between and in the lobules, from which originate the radicles of the hepatic vein, a vessel which carries the blood from the liver to the ascending *vena cava.* The connective tissue of the liver, and its vessels and nerves, are supplied by a special artery, the hepatic artery. The proper secreting structure of the liver consists of numerous compressed cells, about the $\frac{1}{1000}$th of an inch in diameter, called hepatic cells. These cells secrete materials from the blood, which they elaborate into bile. This secretion passes into minute ducts, the hepatic

ducts, the exact mode of origin of which is at present obscure. These ducts convey the bile out of the liver; and after it has become inspissated and mixed with mucus, from small mucous glands in the larger ducts, and from the gall-bladder, it is poured into the duodenum. The liver performs at least three functions: first, the secretion of bile; second, the formation of fat; and third, the formation of animal starch or glycogen. The bile is to be regarded chiefly as an excretion rich in hydro-carbons, but during its passage from the economy, it performs certain functions referred to under Digestion. It is highly probable that part of the bile is re-absorbed into the blood, but its ultimate function is unknown. The amount formed daily is about 3½ pounds; but the quantity is liable to great variation.

The formation of animal starch by the liver is called its *glycogenic function*. It is supposed that this starch, formed in the cells of the liver, is converted by the blood of the hepatic vein into sugar, which is carried to the lungs, where it is decomposed into carbonic acid and water. This, however, is a point not yet conclusively settled.

3. *The Skin.*—This organ, continuous at various points with the internal mucous surfaces, covers the whole body, and consists of two layers: first, a hard epithelium, composed of cells more or less flattened, called the epidermis; and second, of the *derma*, or *cutis vera*, or true skin, which is formed of connective and elastic tissue. Underneath the true skin, we find a layer of fat. We find in the skin two kinds of glands. The sudoriparous or sweat glands, consist of a tube, coiled into a ball at the deeper part, and communicating with the surface by a spiral duct. The sebaceous glands are small racemose glands, which usually open into the hair follicles, and secrete an oily fluid for lubricating the hairs and surface of the skin. The chief excretion of skin is sweat, an acid watery fluid, which is usually carried off from the surface in the form of vapour. The amount varies greatly: from five pounds in the twenty-four hours, to one pound. That the separation of this excretion is important, is proved by the fact, that if the skin be varnished over, so as to prevent exhalation, death may speedily ensue. All the various modifications of epidermis, such as hair, horn, nail, hoof, &c. may also be regarded in the light of excretions, but space compels us merely to allude to this fact.

Fig. 5.—Vertical Section of the Skin of the Sole:

a, cuticle; *b*, papillary structure; *c*, *cutis vera*, or true skin; *d*, sweat-gland lying in a cavity on the deep surface of the skin, and imbedded in globules of fat. Its duct is seen passing to the surface. Magnified about 30 diameters.

4. *The Kidneys.*—The human kidneys are situated in the loins, one on each side of the spine. A well-developed healthy kidney weighs about six ounces. When cut open, we find a cavity communicating with the ureter, the excretory duct of the kidney, and we observe also that the organ consists of two substances, which are named, from their position, the external or cortical, and the internal or medullary substance. The medullary part consists of straight tubules, which divide in two as we pass outwards to the cortical part, while in the latter, the tubes are extremely convoluted. In the cortical part of an injected kidney, there are numerous small round balls of capillaries called Malpighian bodies, after the celebrated anatomist who first observed them. In man they are about the $\frac{1}{120}$th of an inch in diameter. They consist of a mass of minute capillaries supplied with blood by an afferent vessel, and having also an efferent vessel to carry the blood away. Each of these little balls is embraced by the dilated end of one of the uriniferous tubes, as seen in the preceding figure. The function of the kidney is to excrete urine, a fluid rich in nitrogenous materials. The urine is an amber-coloured liquid, having a specific gravity of 1020, a slightly acid reaction, a saltish taste, and an odour peculiar to itself. The chief substance in the urine of man is urea, of which about an ounce is excreted daily, while, during the same time, about eight grains of uric acid are separated. In reptiles, however, the amount of urea is small, while uric acid is largely present. These substances are derived from the waste of the nitrogenous tissues, uric acid being formed before urea. In rapid-breathing, warm-blooded animals, uric acid is rapidly oxidised to urea, and consequently only a small amount of the acid appears in the urine; whereas, in slow-breathing, cold-blooded animals, the oxidation is incomplete. Man being omnivorous, partakes of enough of food rich in carbon to prevent the complete oxidation, and therefore a small amount of uric acid is always found in his urine. The kidneys also separate inorganic matters, such as chlorides, sulphates, phosphates, &c. These are much modified as to amount by the nature of the diet, and the amount of fluid taken with them.

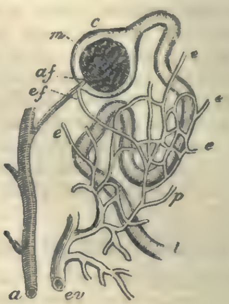


Fig. 6.—Plan of the Renal Circulation:

a, terminal branch of the artery, giving the terminal twig, *af*, to the Malpighian tuft, *m*, from which emerges the efferent vessel, *ef*. Other efferent vessels, *e*, *e*, *e*, are seen proceeding from other tufts, and entering the capillaries surrounding the uriniferous tube, *t*. From this plexus of capillaries the emulgent vein, *ev*, springs.

5. *The Intestines.*—The excretions from the bowel consist not only of the non-nutritious materials of food, bile, mucus, and mineral matters,

but also of fetid effete matters removed from the system by the lower bowel.

II. THE FUNCTION OF INNERVATION.

The vital processes included under the function of nutrition belong to the class of functions known as *vegetative*, because certain of them are common to vegetables as well as to animals. These functions have as their object the preservation of the plant. The animal has, however, another set of organs, by the use of which it becomes conscious of a world external to itself. By means of certain functions, which, from their occurrence in animals

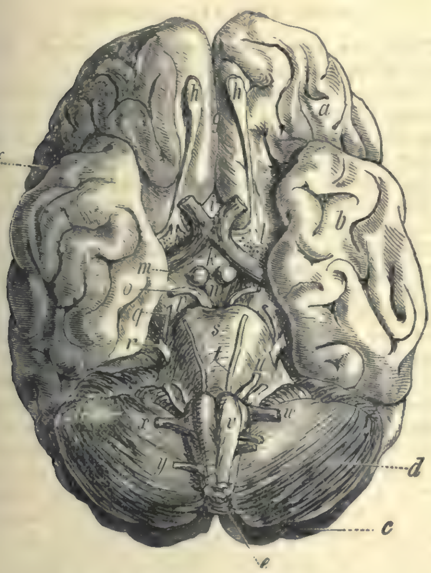


Fig. 7.—Human Adult Brain:

a, anterior lobe of cerebrum; *b*, middle lobe; *c*, posterior lobe of cerebrum, appearing behind; *d*, cerebellar hemisphere; *e*, medulla oblongata; *f*, fissure of Sylvius; *g*, longitudinal fissure; *h*, *h*, olfactory bulbs; *i*, optic commissure—the optic nerves are seen interchanging fibres; *l*, three roots of olfactory process; *m*, white round bodies (*corpora albicantia*), the terminations of the anterior portions of fornix; *n*, where the vessels perforate the brain substance, hence called posterior perforated space; *o*, third pair of nerves coming to supply muscles of the eyeball, from *p*, the crus cerebri; *q*, fourth nerve, turning round from the valve of Vieussens; *r*, fifth pair; *s*, pons varolii; *t*, sixth pair of nerves; *u*, seventh pair, portio dura for muscles of face, and portio mollis for hearing; *v*, posterior pyramids of cerebellum, seen to interchange fibres; *w*, and two below, are eighth pair—viz. glosso-pharyngeal, vagus or pneumo-gastric, and spinal accessory nerve; between *w* and *v* is the small prominence called olivary body; *x*, *y*, two roots of ninth pair of nerves, motor nerve of tongue.

only, are termed *animal*, all the higher creatures, and especially man, are endowed with Sensation, Motion, and Volition. These powers are due to the presence of a Nervous System, including two sets of nerves and nerve-centres—namely, the *cerebro-spinal system* and the *sympathetic system*.

The former consists of the *cerebro-spinal axis*, composed of the brain and spinal cord, and the *cerebral* and *spinal nerves* connected with this axis; while the latter consists chiefly of a double chain of ganglia or nervous masses, lying at the sides of the spinal column, and united with one another and with the spinal nerves by connecting threads of nervous tissue. The sympathetic system influences the heart and blood-vessels, and the intestines. It has the power of stimulating the action of the heart by acting on ganglia in its substance. It maintains the blood-vessels in a certain state of contraction.

The cerebro-spinal axis lies protected in the cavity of the skull and spinal column, and is covered by three membranes, which serve for protection and for the supply of blood.

Nerve-matter is of two kinds, white and gray, and may be readily seen by cutting through the brain of a sheep or of any other animal, when it will be observed that there is an outer layer of gray matter, while the interior is white. In the spinal cord these relations are reversed, the gray matter lying in the centre. The nerves consist entirely of the white tissue. The microscope shews that the gray matter is made up of round, oval, or star-like cells with a nucleus, and sending off prolongations, which either unite with those of other similar cells, or are continued as nerve-tubes. These cells, termed nerve-cells, vary much in size, from the $\frac{1}{5000}$th to the $\frac{1}{400}$th of an inch. The white matter consists of tubes, transparent as glass when examined alive; but immediately after death, shewing two well-defined lines on each side of a broad clear space. They thus appear to consist of two parts—a central part, which probably conducts the nervous influence, surrounded by a substance, of different chemical constitution, which may act as an insulator of the nervous force. A nerve consists of many of these tubes running alongside of each other, and here and there plexuses are formed by certain tubes diverging and running from one nerve to another. The function of the nerve-tube is to receive an impression of any kind, mechanical, chemical, thermal, or volitional, thereupon to generate an influence, and to conduct this influence to or from a nerve-centre. The rapidity of the nerve-current is from 75 to 120 feet per second; incomparably slower than light, or electricity. The nerve-cells either receive or originate nervous force.

The brain consists of the *cerebrum*, or brain proper, which occupies the whole of the upper and front parts of the cavity of the skull; the *cerebellum*, or little brain, lying beneath the hinder part of the cerebrum; and the *medulla oblongata*, or oblong marrow, which may be regarded as a continuation of the spinal cord within the cavity of the cranium, and as forming the connection between the brain and cord. The cerebrum and cerebellum are almost completely bisected into two lateral halves by a deep longitudinal fissure; and the surface of the former is divided by a considerable number of tortuous furrows, nearly an inch deep, into convolutions. As the gray matter is extended into these furrows, its quantity is thus vastly increased.

At the base of the cerebrum, and connected with it, there are two large ganglionic masses of gray and white matter, called the *corpora striata;* behind these, other two bodies of a similar nature, the *optic thalami;* and still farther back, four bodies, two on each side, the *corpora quadrigemina*. All these parts of the brain are connected with each other by numerous tubes. The tubes from the spinal cord pass upwards in the medulla oblongata; those from the posterior part of the cord going chiefly to the cerebellum, while those from the anterior pass to the cerebrum. In the cerebrum,

cerebellum, and ganglia, we also find tubes running from their anterior to their posterior ends, while other tubes run transversely, and unite corresponding parts on opposite sides of the brain. Thus there is evidently community of function.

The functions of these different parts may be briefly stated to be as follows: 1, the *cerebrum* is the seat of Sensation, Volition, Emotion, and of those intellectual powers which constitute MIND; 2, the *cerebellum* is probably the regulator of muscular movements; 3, the *corpora striata* is a great centre of voluntary movement, not of volition, but of the nervous mechanism by which, when we will with the cerebrum, the influences are sent along the spinal cord to the various muscles; 4, the *optic thalami* perform the same function with regard to sensation; 5, the *corpora quadrigemina* receive visual impressions by the optic nerves from the retina of the eyes, and transmit these to the cerebrum, where there is then the consciousness of sight; and 6, the *medulla oblongata*, and an adjoining part called the *pons Varolii*, are the seat of the nervous influences which regulate swallowing, breathing, and other important involuntary movements. The parts of the brain last mentioned (6) are absolutely essential to life. The other parts may be cut or mutilated without instant death, but this surely follows in a few moments injury to the medulla.

Nerves have different functions. When an influence travels along a nerve to a muscle, it excites the muscle to contract, and the former is then called a *motor* nerve; when it travels to the brain and causes a sensation, we call such a nerve *sensory*. Most nerves contain both sensory and motor tubes. Some are purely sensory, as certain parts of the fifth cranial nerve; others purely motor, as the facial, or seventh cranial nerve; while all the spinal nerves are senso-motory. Certain nerves respond only to particular stimuli. For example, the optic nerve is affected only by vibrations of rays of light. Such are called *special sensory* nerves, and include those of sight, hearing, taste, smell. The nerves of touch are those of common sensibility distributed to the skin.

Twelve pair of nerves are given off from the brain, and thirty-one from the spinal cord.

The *spinal cord* or *marrow* is a cylindrical column of soft nervous tissue, extending from the base of the skull, where it is continuous with the *medulla oblongata*, to the region of the loins, where it tapers off to a thread in the lowest part of the vertebral canal. Its average length is eighteen inches. It is not only divided by two fissures in the middle, but each half is again divided longitudinally into three equal parts by two parallel series of nervous filaments, which are the anterior and posterior roots of the spinal nerves. The posterior root presents a swelling or ganglion, immediately beyond which the two coalesce into the trunk of a nerve which, after emerging through a hole called the intervertebral foramen, is distributed into branches to the parts it is destined to supply with nervous filaments; as, for example, the muscles of the trunk and limbs and the surface of the body. These roots have separate functions, the anterior being composed of motor, while the posterior contain sensory tubes. Hence if the anterior root (in a vivisection operation) is divided, or if the column of the cord from which it springs is diseased, loss of motion in the part which it supplies is the result; while if the posterior root were similarly acted on, there would be loss of sensation. The anterior columns of the medulla decussate (that is, send nerve-tubes across to the adjoining column); while many of the tubes of the posterior columns decussate all the way up the back of the cord. Consequently, injury to the right anterior column causes loss of motion on the same side, while injury to the right posterior column paralyses sensation as regards the opposite side of the body. The decussation of the anterior columns in the medulla also explains how a clot of blood in the right hemisphere of the brain, as in apoplexy, causes loss of motor-power on the left side of the body.

THE SPECIAL SENSES.

There are five senses—namely, *touch*, *taste*, *smell*, *sight*, and *hearing*.

Touch.—The sense of touch, including that of different degrees of heat, is possessed by the skin, by the walls of the mouth and nostrils, and by the tongue, but it is most highly developed on the tips of the fingers. The essential organs of this sense are the true skin, containing capillaries, and the terminations of sensory nerves. On examining the surface of the true skin by a magnifying-glass, we can see a regular arrangement of papillæ, or cone-like projections about $\frac{1}{100}$th of an inch in length. In many of these papillæ there are found small round or oval bodies made of hard fibrous tissue, and having a nerve-tube coiled round them, and sometimes penetrating into their interior. These are called *touch-bodies*. They serve as resisting structures against which the nerve may be pressed, and thus the sense of touch may be intensified. When one of those nerves is pressed by the contact of any foreign body, an influence is produced which travels to the brain, where we become conscious of the impression. This consciousness, however, we refer not to the brain, but to the part affected; a subjective power, which is probably the result of experience.

Taste.—The organs of taste are in the mucous membrane of the tongue, especially at its back part. The nerves of taste are the lingual branch of the fifth cranial nerve and the glosso-pharyngeal, the former supplying the anterior two-thirds, and the latter the posterior one-third of the tongue. The mucous membrane of the tongue presents papillæ of various forms, called *filiform*, or thread-like; *fungiform*, or mushroom-like; and *circumvallate*. The circumvallate are about thirteen or fifteen papillæ set in the form of a V with its point backwards, and each resembles a fungiform papillæ surrounded by a wall. These last-named structures are regarded as the essential organs of taste. They derive their nerves chiefly from the glosso-pharyngeal nerve. The contact of a sapid body with the surface of the tongue is not sufficient to evoke the sense of taste. The substance must be dissolved, and to effect its solution nature provides a special fluid—the saliva. In febrile diseases, in which the tongue is dry and coated, the sense of taste is either dormant or perverted. Taste is more acute in some persons than in others. It is sometimes blended in a remarkable way with smell, giving rise to the peculiar sensation we call flavour. The sensations produced by

the contact of mustard, pepper, &c. with the tongue are not those of taste, but rather exaggerated forms of touch.

Smell.—The organ of the sense of smell is the mucous membrane lining a part of the nasal cavities supplied with nerves from the *olfactory* bulbs or first pair of cranial nerves. Attached to the side-walls of each nasal cavity are two delicate scroll-like bones, called turbinated bones, which to a great extent divide each cavity into three spaces, lying one above the other. The two uppermost of these constitute the true olfactory chambers, while the lowest passage is merely used for respiratory purposes. The whole of this bony framework is covered by moist mucous membrane, having imbedded in it flat elongated plates attached to the ramifications of the olfactory nerves. By the contact of certain substances with these, a sensation of smell is produced. According to Graham, 'all odorous substances are in general such as can be readily acted on by oxygen.' Animal effluvia keep near the soil, hence the bloodhound runs with the nose to the ground. The sense of smell is extremely delicate in most individuals. It is soon blunted, and consequently many who live among disagreeable odours do not perceive them. A distinction must be drawn between a smell proper, like that of a violet, and the irritation produced by the fumes of ammonia. The close stuffy sensation experienced on entering an ill-ventilated crowded apartment, is due chiefly to interference with the free play of respiration.

Sight or Vision.—The sensation of light results from the influence produced on the sensitive expansion of the filaments of the optic nerve by vibrations of a delicate and subtle substance known as

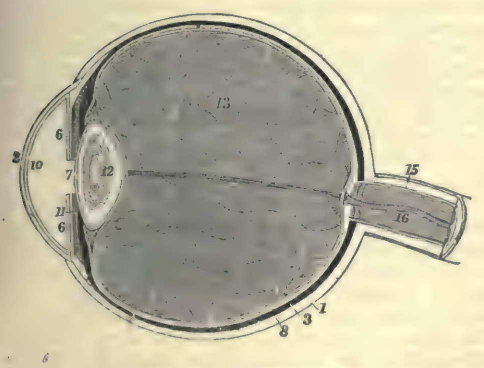


Fig. 8.—A longitudinal section of the Coats of the Eye:

1, the sclerotic, thicker behind than in front; 2, the cornea; 3, the choroid; 6, the iris; 7, the pupil; 8, the retina; 10, the anterior chamber of the eye; 11, the posterior chamber; 12, the crystalline lens, inclosed in its capsule; 13, the vitreous humour, inclosed in the hyaloid membrane, and in cells formed in its interior by that membrane; 15, the sheath; and 16, the interior of the optic nerve, in the centre of which is a small artery.

'ether.' But the falling of light upon the optic nerve itself will produce no sensation. An intermediary apparatus is necessary—the retina, which is an expansion of nervous matter placed behind the optic nerve.

The *globe of the eye* is placed in the anterior part of the orbit, in which it is held in position by its connection with the optic nerve posteriorly, and with the muscles which surround it, and by the eyelids in front. It is further supported behind and on the sides by a quantity of fat.

The eyeball is composed of several investing membranes, and of certain transparent structures, which are inclosed within them. These transparent structures act as refractive media of different densities, so that rays of light entering the eye are so bent as to come to a focus on the retina. Thus a distinct image is formed. These refractive structures are from before backwards—1st, the cornea, like transparent horn; 2d, the aqueous humour, like water; 3d, the lens, like glass; and lastly, the vitreous humour, like clear jelly.

The outermost coat of the eye is the *sclerotic* (from *skleros*, hard). It is a strong, dense, white, fibrous structure. Posteriorly, it is perforated by the optic nerve. This coat, by its great strength and comparatively unyielding structure, maintains the inclosed parts in their proper form, and serves to protect them from external injuries.

The *choroid coat* is a dark-coloured vascular membrane, containing pigment cells. In front, it ends by means of the ciliary processes, which consist of about sixty or seventy radiating folds. These fit into depressions in the suspensory ligament of the lens, and assist in keeping it in its proper position.

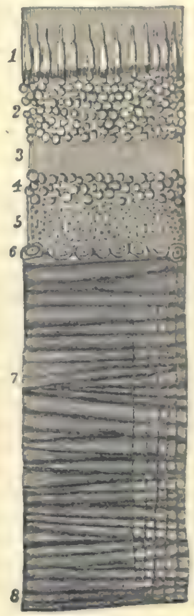


Fig. 9.—A Vertical Section of the Human Retina:

1, the layer of rods and cones (Jacob's membrane); 2, the external granular layer; 3, the intervening layer between 2 and 4, the internal granular layer; 5, finer granular layer; 6, layer of nerve-cells; 7, fibres of the optic nerve; 8, limitary membrane.

The *iris* may be regarded as a process of the choroid, with which it is continuous. It is a thin flat curtain, hanging vertically in the aqueous humour in front of the lens, and perforated by the pupil for the transmission of light. It is composed of unstriped muscular fibres, one set of which being arranged circularly round the pupil, and, when necessary, effecting its contraction; while another set lie in a radiating direction from within outwards, and by their action dilate the pupil. Thus more or less light may be admitted into the eye, and its function is like that of the diaphragm in many optical instruments.

The varieties of colour in the eyes of different individuals and of different kinds of animals, mainly depend upon the colour of the pigment, which is deposited in cells in the substance of the iris.

Within the choroid is the *retina*. With the naked eye it is seen to be a delicate semi-transparent sheet of nervous matter, lying immediately behind the vitreous humour, and extending

from the entrance of the optic nerve nearly as far as the lens. On examining the retina at the back of the eye by an instrument called an ophthalmoscope, we observe, directly in a line with the axis of the globe, a circular yellow spot called, after its discoverer, the yellow spot of Sömmering. The only mammals in which it exists are man and the monkey. It is the point of distinct vision. When we read a book, we run the eye along the lines so as to bring portions of the line successively on the yellow spot. If, on the other hand, we carefully fix our attention on a word in the middle of the line, we see the word distinctly, because it is on the yellow spot, while the words towards each end of the line are less distinct, being on other portions of the retina.

The structure of the retina, as revealed by the microscope, is seen in fig. 9.

The *transparent media* through which rays of light must pass before they form on the retina the images of external objects are:

Immediately behind the transparent cornea is the *aqueous humour*, which fills up the chamber between the cornea and the lens. It is nearly pure water, with a trace of chloride of sodium.

The *crystalline lens* lies opposite to and behind the pupil, close to the iris, and its posterior surface is received into a depression on the forepart of the vitreous humour (see fig. 8). In form, it is a double-convex lens, with surfaces of unequal curvature, the posterior being the most convex, and the curvature is also less at the centre than towards the margin.

The *vitreous humour* lies in the concavity of the retina, and occupies about four-fifths of the eye posteriorly.

The appendages of the eye are:

1. The *muscles* by which the eye is moved are four straight (or *recti*) muscles, and two oblique (the superior and inferior). By the duly associated action of these muscles, the eye is enabled to move (within definite limits) in every direction.

2. The *eyelids* are two thin movable folds placed in front of the eye, to shield it from too strong light, and to protect its anterior surface. The eyelashes intercept the entrance of foreign particles directed against the eye, and assist in shading that organ from an excess of light.

3. The *lachrymal apparatus* consists of the lachrymal gland, by which the tears are secreted; two canals, into which the tears are received near the inner angle of the eye; the sac, into which these canals open; and the duct, through which the tears pass from the sac into the nose. The constant motion of the upper eyelid induces a continuous gentle current of tears over the surface, which carry away any foreign particle that may have been deposited on it.

The various uses of the different structures of the eye are readily understood. Assuming a general knowledge of the ordinary laws of geometrical optics, we will trace the course of the rays of light proceeding from any luminous body through the different media on which they impinge. If a luminous object, as, for example, a lighted candle, be placed at about the ordinary distance of distinct vision (about ten inches) from the front of the eye, some rays fall on the sclerotic, and being reflected, take no part in vision; the more central ones fall upon the cornea, and of these some also are reflected, giving to the surface of the eye its beautiful glistening appearance; while others pass through it, are converged by it, and enter the aqueous humour, which probably, also, slightly converges them. Those which fall on and pass through the outer or circumferential part of the cornea are stopped by the iris, and are either reflected or absorbed by it; while those which fall upon its more central part pass through the pupil. The rays now impinge upon the lens, which, by the convexity of its surface, and by its greater density towards the centre, very much increases the convergence of the rays passing through it. They then traverse the vitreous humour, whose principal use appears to be to afford support to the expanded retina, and are brought to a focus upon that tunic, forming there an exact, but inverted image of the object.

Accommodation of the Eye to Distance.—It will be found on experiment that we cannot see a distant and a near object at the same moment. For example, if we look through a railing at a distant church spire, and fix our attention on the spire, we do not distinctly see the railing; and *vice versâ*. This was early observed; but, until recently, the mechanism by which the eye accommodates or focuses itself for different distances was unknown. Cramer was the first to point out that if we bring a candle-flame near the eye in a dark room, we may see three images—1st, an erect image reflected on the cornea; 2d, an erect image on the anterior surface of the lens; and 3d, an inverted and very faint image on the posterior surface of the lens. He also shewed that when the eye looks quickly at a near object, after having been for some time directed to a distant one, the middle image moves forward nearer to the first, and also becomes smaller, shewing that for near vision the anterior surface of the lens becomes more convex. Helmholtz afterwards, by means of an instrument called the ophthalmometer, measured the sizes of those reflections, and, from certain data, calculated by mathematical formulæ the radii of curvature of the reflecting surfaces; and he shewed conclusively that the accommodation of the eye for different distances is effected by changes in the curvature of the anterior surface of the lens. The physiological explanation is as follows:

The lens, which is elastic, is kept habitually in a state of tension by the pressure of the suspensory ligament, and consequently has a flatter form than it would take if left to itself. When the ciliary muscle contracts, it relaxes the ligament, and thereby diminishes its elastic tension upon the lens. The lens, consequently, becomes more convex, returning to its former shape when the ciliary muscle ceases to contract.

There are two common forms of defective vision which require notice—namely, short-sightedness or *myopia*, and long-sightedness or *presbyopia*. They are due to an abnormality either in the curves or in the density of the refracting media. In *short-sightedness* from too great a refractive power from either cause, the rays from objects at the ordinary range of distinct vision are brought too soon to a focus, so as to cross one another, and to diverge before they fall on the retina; the eye in this case being able to bring to the proper focus on the retina only those rays which were previously diverging at a large angle from a very near object. The correction for this deficiency is accomplished by interposing between the eye

and indistinctly seen objects a *concave* lens, with a curvature sufficient to throw the images of external objects at the ordinary distance of distinct vision backwards upon the retina. In *long-sightedness*, on the other hand, there is an abnormal diminution of the refractive power, so that the focus is behind the retina. This defect is corrected by a *convex* lens, which increases the convergence of the rays of light.

Position of Objects on the Retina.—In consequence of the bending of rays of light by the refractive media, the image of an external object is inverted on the retina, and yet we see objects erect. The probable explanation is, that the mind may perceive as correctly from an inverted as from an erect image. When we glance at a column from top to base, we move the eyeball downwards so as to bring successive parts on the yellow spot, and it is the feeling of movement which informs us which is top and which is base, not the inverted position on the retina, of which we are really unconscious.

Single Vision with two Eyes.—This phenomenon is explained by the fact that there are corresponding points on the retina, so that when, by the regular action of the muscles of the eyeball, an image is formed on a corresponding point in each eye, the mind is conscious of one image. If we alter the direction of the axis of one eye by pressing gently on the ball, an image is formed on a point of the retina of that eye which does not correspond, and consequently we squint, or see two images.

Hearing.—The organ of hearing is composed of three portions, the external, middle, and internal ear. The external ear consists of the auricle, which

Fig. 10.—General view of the External, Middle, and Internal Ear, shewing the interior of the auditory canal, tympanic cavity, and Eustachian tube:

a, the auditory canal; *b*, the tympanum; *c*, the Eustachian tube, leading to the pharynx; *d*, the cochlea; and *e*, the semicircular canals and vestibule, seen on their exterior by the removal of the surrounding bony tissue.

presents elevations and depressions, the functions of which are to receive and reflect the vibrations of the air which constitute sound, and to transmit these by a tube, partly cartilaginous, partly bony, called the auditory canal, to the middle ear. The middle ear is named the tympanum or drum. It is a cavity in the petrous or hard portion of the temporal bone. It is shut off from the auditory canal by the membrane of the drum, a thin structure capable of vibrating when acted on by the vibrations of the air. The tympanum communicates with the back of the throat by the Eustachian tube, the function of which is to equalise atmospheric pressure on both sides of the vibrating membrane. When this tube becomes stopped mechanically by enlargement of the tonsils, partial deafness is the result, and when cleared so as again to allow air to pass into the tympanum, hearing at once returns to its normal state. Across the tympanum, we find a chain of small bones, one of which, the malleus, or hammer, is attached by a long handle to the drum; this unites by a joint with another, the incus, or anvil; which in turn bears the stapes, or stirrup, the base of this being fixed to a small oval membrane closing an aperture, called the fenestra ovalis, which communicates with the internal ear. The function of this

Fig. 11.—Ossicles of the Left Ear, as seen from the outside and below:

m, head of the malleus; *g*, the slender process, or *processus gracilis*; *h*, the manubrium or handle; *sc*, the short crus, and *lc*, the long crus of the incus; *a*, the position of the lenticular process, through the medium of which it articulates with the head of the stapes; *s*, the base of the stapes. Magnified three diameters.

chain of bones is to convey vibrations from the membrane to the internal ear. The internal ear, or labyrinth, so called on account of its complexity of structure, is the essential part of the organ of hearing, because here we find the filaments of the auditory nerve which are ultimately to receive impulses originally produced by vibrations of the air, and which are conveyed by the intermediate structures already described. It is made of three parts—the vestibule, or central part; the semicircular canals, three in number, which communicate posteriorly by five openings with the vestibule; and the cochlea, so called from its resemblance to a snail-shell. Each of these parts is excavated from the substance of the bone, and forms the bony or osseous labyrinth; but within this we have a fibrous structure, exactly corresponding in shape, the membranous labyrinth. The osseous is separated from the membranous labyrinth by a fluid called the *perilymph*, and within the membranous portion there is another fluid, called the *endolymph*. The terminations of the auditory nerve are distributed on the walls of the membranous portion, and by the presence of the two fluids just mentioned, the most delicate vibrations of the air communicated directly to the drum and chain of bones, or indirectly through the bones of the head, are conveyed to the nerves. The structure of the cochlea is very remarkable. It consists of a central pillar, round which a tube makes two and a half coils. This tube is divided into two compartments

by a partition, partly bony, partly membranous. The upper portion communicates with the vestibule, and, from its fancied resemblance to a stair, has been called *scala vestibuli*. Suppose we ascended this stair to the apex of the cochlea, we would there find a small opening communicating with the lower compartment, which has been called the *scala tympani*. It received this name because at the bottom it communicates with the tympanum by a round opening, called the *fenestra rotunda*, closed by a thin membrane. The cochlear branch of the auditory nerve enters the base of the pillar just mentioned, and distributes branches to the membranous portion of the scalæ. But this is not all. Between the two scalæ or staircases, in a triangular space, there is a remarkable organ, called the *Organ of Corti*. This is a complicated anatomical structure, which space will not allow us fully to describe here, but essentially it consists of three or four thousand jointed rods, apparently capable of vibrating, and presenting, when viewed from above, an appearance somewhat like the key-board of a piano.

We know little regarding the functions of the different parts of the internal ear. That they have different functions, we infer from the structure being so dissimilar, and also from the facts of comparative anatomy. In the animal kingdom, the vestibule first appears; to this are superadded the semicircular canals; and lastly, the cochlea, which increases in complexity from the lower orders of the mammalia up to man, in whom it is one of the most complicated organs of the body. The vestibule probably enables us to experience a sensation of sound as such; the semicircular canals may, as suggested by Wheatstone, assist in determining the direction of sounds; while there are many arguments in favour of the view, that the cochlea, as we find it in man, with a highly elaborated organ of Corti, may be the mechanism by which we appreciate musical sounds, which act so powerfully in exciting the emotions.

The range of hearing, like that of vision, varies in different persons. Some are insensible to sounds that others hear. Many cannot hear the chirp of a grasshopper or the squeak of a bat, two of the shrillest sounds in nature. The range of the ear is much greater than that of the eye in detecting movements which produce vibrations. Thus we hear the sound produced by a vibrating rod or string long after we have ceased to see the movements. The range of the human ear is probably nine or ten octaves.

The Muscular Sense.—There is still another sense, called the muscular sense, or sense of weight. If we close our eyes, and hold a weight on the palm of the outstretched hand, we experience a peculiar sensation. It is not referable to any of the five senses, except, perhaps, to touch. But it is not simple touch. We are conscious of an effort to sustain the weight, and of a firm condition of the muscles of the arm. This sensation is the muscular sense. It is the sensation we experience when any groups of the voluntary muscles are called into action, and by it we become aware of the condition of these muscles. By means of this sense, we stand erect, we walk, balance ourselves on a narrow ledge, throw stones or weapons, play on many instruments, &c.; and it adds largely to our feelings of pleasure.

VOICE AND SPEECH.

There is a great difference between voice and speech. Voice is produced by vibrations of two thin folds of membrane called the vocal cords, placed in the larynx, at the top of the trachea or windpipe: speech is the modification of voice into sounds connected with certain ideas produced by the action of the brain, which we wish to communicate to our fellow-men. Many animals have voice; none, except man, have articulate speech expressive of ideas. The organ of voice is the larynx (behind the *Pomum Adami*), the structure of which is very complicated, and cannot be here described. It consists of various cartilages and muscles, the object of which is to tighten or relax the margins of two folds of membrane, called the *vocal cords*. By the vibrations of these cords voice is produced, and by tightening or relaxing, separating or approximating them, we obtain various modifications of voice. When a high note is sounded, the cords are tense and close together; and, on the contrary, when we sing a deep bass note, they are relaxed and wide apart. The quality and compass of the voice differ in individuals. In men, the highest is the tenor; the lowest, the bass; the intermediate, the barytone. In women, the corresponding notes are the soprano, the contralto, and the mezzo-soprano. The difference between the deep bass of a man and the shrill soprano of a woman, is, that in the man the cords are longer and less tense than in the woman.

Speech is voice so modified by the action of the throat, tongue, cheeks, and lips, as to mean or indicate objects, properties, ideas, &c. This is language. If we breathe quietly, without causing the vocal cords to vibrate, and modify by the action of the mouth, &c. the volume of air expelled, we produce *whispering*.

III. FUNCTION OF REPRODUCTION.

The third great function of animal life is reproduction, by which the species is perpetuated. It is beyond the scope of this article to treat of this subject, and reference is accordingly made to special works on Anatomy and Physiology.

ZOOLOGY.

ZOOLOGY (from Greek *zōon*, an animal, and *logos*, a discourse) treats of the form and structure of animals, and the characters by which they may be distinguished from each other.

All natural bodies may be divided into two great groups—mineral or inorganic, and living or organic. The organic are again subdivided into vegetables and animals. Hence arises the division of all natural objects into three great kingdoms—namely, the *Mineral*, *Vegetable*, and *Animal*.

Inorganic substances never *live*. Chemically, they may be simple or compound, such combinations usually forming binary or ternary compounds. Their physical condition may be solid, fluid, or gaseous; but they are homogeneous in texture, that is, any detached portion exactly resembles the remainder in composition and properties. They may be amorphous, without distinct forms; or crystalline, that is, having distinct geometrical forms, bounded by plane surfaces, which have a definite relation to each other. They increase by the addition of like particles to their surface, which is termed *accretion* or *juxtaposition*. Their atoms are at rest, unless set in motion by some physical force acting from without: they initiate no change or motion.

An *organic being* either *lives* or has lived during some part of its existence. Chemically, it consists of few elements, which unite to form ternary and quaternary compounds. It consists of solid and fluid parts, which exercise a reciprocal action on each other. It is bounded by curved lines, and has convex and concave surfaces. Each organised being, under the influence of life, assumes a characteristic, though not absolutely definite shape. It increases or grows by receiving into its interior matter which it elaborates and assimilates. The old particles are being constantly removed, and replaced by new ones, so that all its parts are in constant motion, and are ever changing. It arises from some pre-existing organism of the same kind, by means of a *germ*, which becomes separated, and enjoys an individual existence.

We do not know 'life' apart from matter; some material substratum or 'physical basis' is required for its manifestation. This, according to Huxley, is furnished by what he calls *protoplasm*, which is a homogeneous, structureless substance, endowed with contractility, and having a chemical composition nearly allied to that of albumen: it is composed of carbon, hydrogen, oxygen, and nitrogen. This term *life* indicates a very special property indeed; and at present, looking at it from a purely material point of view, we are scarcely justified in regarding *life* as more than that condition of an organised being in which the products of chemical and physical changes taking place within it are stamped with a *specific form*. By the term 'moulding of specific form' is meant the building up of a complicated and heterogeneous organism, which repeats the characters which have been transmitted to it through a germ, by a parent, every molecule of every part having thus a direct relation in form, in position, and in composition, to every other molecule of the body.

It is impossible to draw a distinct line of demarcation between vegetables and animals, as the lowest forms of both kingdoms seem to meet and merge into each other. It was on this account that Professor Ernst Haeckel of Jena constructed a fourth kingdom, called by him 'Protista,' into which he proposed to put all the organisms of doubtful affinity. But this, at present, seems scarcely justifiable. Of course, the conspicuous members of the vegetable kingdom can never be confounded with the higher animal forms. In the latter, the presence of a nervous system, the possession of a mouth and digestive cavity, as well as the power of voluntary locomotion, are sufficient to distinguish them from the former, in which all these are absent. In the simplest groups in each kingdom, however, these grand distinctions are lost. *Chemically*, plants consist chiefly of ternary compounds—that is to say, compounds consisting of three elementary ingredients, as starch and cellulose, which are different combinations of oxygen, hydrogen, and carbon. In an animal, quaternary, and still more complex compounds, as albumen, fibrine, and gelatine, make up the bulk of the body; while ternary compounds, though, indeed, not wanting, play a subordinate part. The *general plan of nutrition* is strongly contrasted in the two kingdoms; but in some low animal forms, as the Gregarinæ, nutrition is effected by absorption through the external surface, just as is the case in plants. Most plants are permanently fixed in the ground by roots, but some low forms of algæ are locomotive; and although most animals can move about from place to place, others are incapable of progression, as the branched and tree-like sponges. It may be said, in a general sense, that *organs of relation* are present in animals, and absent from plants. But some phenomena connected with climbing plants, and with the process of fertilisation, are very difficult to explain without admitting some low form of a general harmonising and regulating function, comparable to such an obscure manifestation of reflex nervous action as we have in Sponges and other animals in which a distinct nervous system is absent.

Plants can secrete and store in their leaves and other parts a substance called 'chlorophyl,' by means of which, under the influence of light, they absorb carbonic acid from the atmosphere, decompose it, and, when the carbon is in a nascent state—that is, just liberated from combination—can combine it with the elements of water (hydrogen and oxygen), or with the elements of water and ammonia, likewise reduced to a nascent state by the same agency. The plant thus gains from the air and from the soil certain elementary substances, chiefly carbon, oxygen, hydrogen, and nitrogen. These, under the guidance of a vital property, and through the

medium of protoplasm contained in its cells, it combines into still more complex organic compounds, which contribute to the development or maintenance of the special specific form of the organism of which it is a part. Plants can assimilate no elementary substance except oxygen, unless it is presented to them in the nascent condition.

An animal stands in exactly the same relation to the binary compounds, carbonic acid, water, and ammonia, which, along with salts, form the food of plants. An animal cannot assimilate these substances directly; they must first be elaborated to the condition of ternary and quaternary compounds, which can be done only by the cells of plants. This is the broad and practical distinction between the vegetable and the animal kingdom. Plants possess the power of absorbing, modifying, and organising inorganic substances; while animals are entirely dependent for their support upon the organic substances thus prepared.

The pale growing parts of plants have precisely the same vital properties and relations as animal protoplasm. It is only in cells in which protoplasm elaborates and incorporates with itself colouring-matter (endochrome), which seems to be a more powerful catalytic agent, capable of disengaging the component atoms of the more stable binary compounds, when loosened by the vibrations of light, that the special function of the vegetable cell is manifested. Further, in the interior of the cells of some plants, as *Chara*, the movements of the protoplasm are so special and characteristic as to prove its absolute identity with the protoplasm of the Rhizopods.

A living being is a complicated machine, which does a great deal of various work. One of the higher animals, to take an example, is made up of a great many parts, each of which does its own special part of that work—thus, the stomach digests, and the eye sees. These several parts are called *organs*, and the thing which an organ does is called its *function*. If we remove these organs, performing each its function, one by one, the whole animal disappears. The animal body therefore consists of the sum of its organs.

Living beings may be studied under three principal aspects—the Morphological (*morphē*, form, and *logos*, a discourse), the Physiological, and the Distributional.

Morphology, which treats of the *form* and structure of living beings, includes anatomy, both naked-eyed and microscopic; to the latter, the term Histology (*histos*, a web, and *logos*) has been applied. It also embraces Embryology, or the study of the forms of living beings in all stages of development, from their earliest or immature condition, till they reach their mature or adult state.

Physiology treats of the *functions* of the organism as a whole, or of its separate component parts, organs, or tissues; of what an animal *does*, or of what its different parts do. The functions of an organism are divisible into—1. Function of Nutrition. 2. Function of Generation or Reproduction. 3. Function of Irritability or Correlation.

The *function of nutrition* has reference to the support and maintenance of the body. Matter is introduced into the interior of the body; there it undergoes certain changes, which assimilate it to, and fit it to be incorporated with, the textures which compose the body. *The function of reproduction* serves the purpose of perpetuating the species. The function of nutrition and the function of reproduction have been called the functions of 'organic' or 'vegetative' life, because they are possessed both by plants and animals. *The functions of relation*—including irritability, consciousness, sensation, and volition, with all the movements depending upon the will—bring the organism into connection with the outer world, and the outer world into connection with the organism, so that thus the one reacts upon the other. This group of functions is possessed by animals alone, so that they have been called the 'functions of animal life.'

Distribution treats not only of the areas of the globe over which organisms are distributed, and the conditions under which they exist, but it also relates to the history of life in bygone ages, as furnished to us by the evidence of fossil remains. The former is called distribution in space, or geographical distribution; the latter, distribution in time.

Classification.—On looking at the multitude and variety of animal forms around us—such as we are familiar with as inhabitants of this country, or as natives of other climates collected for our observation—the mind naturally associates together those which have the greatest general resemblance, and separates these (although differing in some degree amongst themselves) from those with which they have greater dissimilarity. Now, it is necessary that some system of arrangement or classification should be adopted, by bringing together those animals which most closely resemble each other, not so much in external appearance as in *internal structure*, in order that the mind shall be the better able to grasp the facts of zoological science. A classification, therefore, will be correct in proportion to the number of ascertained facts upon which it is founded. Zoologists, in seeking to classify animals, are in the habit of using several terms, one of the most important being *species*. It is by no means easy to define this term. It is generally understood to mean an assemblage of animals that resemble each other in all essential points of structure, and which are supposed all to have descended from the same parent stock. A test to which much importance has been assigned, is founded on the supposed fact, that when the animals of different species breed together, their offspring is barren. This offspring is called a *hybrid*—thus, a mule is a hybrid between a horse and an ass. This, however, is not an absolutely satisfactory or conclusive test of specific identity, as hybrids between undoubtedly distinct species have been known, though rarely, to breed and produce fertile offspring.

Until lately it has been the almost universal belief among naturalists that species are permanent within very narrow limits of variation; that is to say, that any group of animals which present the same specific characters, characters which lead an educated observer to set them down as the same thing — for example, all common partridges, or, to take a variable species, all domestic dogs—are descended from an ancestry which can by no possibility include anything except partridges or dogs, and can never, under any circumstances, or through the lapse of any amount of time, give origin to anything except dogs or partridges. This view, of course, involves

the admission of the special creation of a single progenitor for each species, or of two, according as the sexes may be united or distinct. As Edward Forbes expresses it (*Natural History of the British Seas*, page 8): 'Every true species presents in its individuals certain features, *specific characters*, which distinguish it from every other species; as if the Creator had set an exclusive mark or seal upon each type.' From time to time, however, naturalists of high eminence, and among them the celebrated French zoologist Lamarck, dissented from this view, and contended that the weight of evidence was rather in favour of a gradual development of the whole animal series from the simpler to the more complex; a development comparable in certain respects to the development of the individual from the germ to maturity.

The 'doctrine of evolution' has assumed various forms more or less plausible. It will be sufficient here to give a slight sketch of the latest of those speculations, the one which has received the widest acceptance, and exerted the most powerful influence upon the current of human thought—the 'Darwinian theory' of the origin of species by natural selection.

This speculation—for it cannot be said to have assumed any more definite form—is based upon the known phenomena of variation.

It is very evident that offspring have a tendency to resemble their parents very closely in form and structure; and this resemblance, in all cases within our experience, brings parent and offspring within the limit of the same species.

It is equally evident that offspring have a tendency to differ individually from their parents to a certain degree, but this variation is slight, involving no specific distinction; and in no case, so far as we are at present aware, interfering with the power of reproduction, or with the fertility of the succeeding generation.

The range of variation of the individuals composing a species is thus very definite, and is limited by the circumstances under which the group of individuals is placed. Except in man and in domesticated animals, in which it is artificially increased, this individual variation is usually so slight as to be inappreciable, except to a practised eye; and any extreme variation which passes the natural limit in any direction clashes in some way with surrounding circumstances, and is dangerous to the life of the individual. The normal line or 'line of safety' for any species lies midway between the extremes of variation.

If at any period in the history of a species the conditions of life of a group of individuals of the species be gradually altered; if, for example, the temperature of the region which they inhabit be changed, or if there be an alteration in the amount or kind of food, with the gradual change of circumstances, the limit of variation is contracted in one direction and relaxed in another; it becomes more dangerous to diverge towards one side, and more desirable to diverge towards the other, and the position of the lines limiting variation is thus altered. The 'normal line' along which the specific characters are most strongly marked is consequently slightly deflected, some characters being more strongly expressed at the expense of others. This deflection, carried on for ages in the same direction, must eventually carry the divergence of the varying race far beyond any limit within which we are in the habit of admitting identity of species. Those individuals in which the favourable variation is most marked will have the advantage in this struggle for life; will be the stronger and the more comely, and will naturally select one another as partners for the perpetuation of the race; thus continuing and exaggerating the favourable peculiarity from generation to generation.

We must admit that variation is a *vera causa*, capable, within a limited period, under favourable circumstances, of converting one species into what, according to our present ideas, we should be forced to recognise as a different species. And such being the case, it is, perhaps, conceivable that during the lapse of a period of time—still infinitely shorter than eternity—variation may have produced the entire result. There is no doubt great difficulty in imagining that, commencing from the simplest living being, the present state of things in the organic world has been produced solely by the combined action of 'atavism' and 'variation;' and many are still inclined to believe that some other law than the 'survival of the fittest' must regulate the existing marvellous system of extreme and yet harmonious modifications. Still, we are probably justified in saying that there is now scarcely a single competent general naturalist who is not prepared to accept some form of the doctrine of evolution. But the process must be infinitely slow. It is difficult to form any idea of ten, fifty, or a hundred millions of years, or of the relation which such periods bear to changes taking place in the inorganic world. But if it be possible to imagine that this marvellous manifestation of Eternal Power and Wisdom involved in living nature can have been worked out through the law of 'descent with modification' alone, we shall certainly require the longest row of figures which the inexorable physicists can afford.

The origin of species by descent with modification is as yet only an hypothesis. During the whole period of recorded human observation, not one single instance of the change of one species into another has been detected; and, singular to say, in successive geological formations, although new species are constantly appearing, and there is abundant evidence of progressive change, no single case has yet been observed of one species passing through a series of inappreciable modifications into another.

To a number of species agreeing in most points of importance, and having kindred characters, and these characters appealing broadly to the senses, the term *genus*—meaning a kind—is applied. From the arrangement of species of animals in genera has sprung the modern system of zoological nomenclature, first adopted by the celebrated Linnæus. This system has received the name of the *binomial system*, from the fact that each animal receives two names, one belonging to itself alone, and the other which it possesses in common with the other species of the genus under which it is placed. Thus, the genus *Equus* contains the Ass, Horse, and Zebra as species. To all, the generic name *Equus* is applied; but a second or specific name is added to each, to distinguish it from all other species of the genus: thus, the Horse is called *Equus caballus*; the

Zebra, *Equus zebra;* and the Ass, *Equus asinus.* A number of genera with more common characters are usually grouped as an *order:* for example, the Ruminant animals, as cattle, deer, &c. form an order. Sometimes, however, a group of genera, with certain characters in common, is called a *family;* for example, the crow, jay, magpie, chough, &c. form the family *Corvidæ.* In these instances, a group of families forms an order. To a combination of orders, the term *class* is applied—for example, birds, fish, reptiles. Then we come to characters still more general, according to which the entire animal kingdom has been subdivided into six *sub-kingdoms.* These have also been called *morphological types,* and are, as it were, the great ground-plans upon which the Divine Architect has constructed all animals. Thus, we have Sub-kingdoms, Classes, Orders, Families, Genera, Species, and Varieties, each term in succession being applicable in a more and more particular way than its predecessor.

The six sub-kingdoms or morphological types of the animal kingdom are:

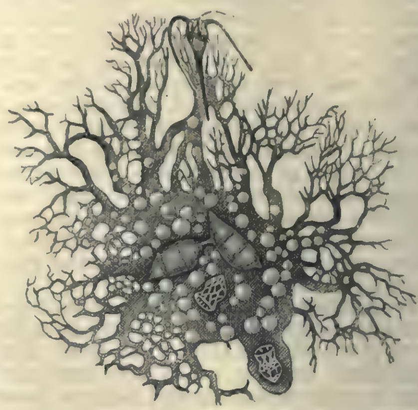
I. PROTOZOA—for example, amœba, sponges, infusoria.
II. CŒLENTERATA—for example, sea-anemones, sea-firs, corals.
III. ECHINODERMATA—for example, sea-urchins, star-fish.
IV. ANNULOSA, or Ringed Animals—for example, insects, spiders, worms.
V. MOLLUSCA, or Pulpy Animals—for example, sea-mats, oysters, cuttle-fish.
VI. VERTEBRATA, or Back-boned Animals—for example, fishes, birds, reptiles, and man.

I. SUB-KINGDOM PROTOZOA.

The Protozoa (Gr. *protos,* first, *zōon,* animal—the beginnings of life) are usually minute, and many of them can be seen only by the aid of the microscope; but sometimes they are of considerable size, for example, the sponges. They are formed of a jelly-like substance called 'sarcode,' or 'protoplasm,' which exhibits little or no trace of structure, resembling closely raw white of egg, more or less firm. In most is found a small solid body, the 'nucleus,' which, from recent observations, appears to be an ovary; and near this, one or two still more minute particles, the 'nucleoli,' which seem to be cells containing fertilising filaments. In many, contractile vesicles have been observed, spaces filled with a clear fluid which is driven by a contraction of the wall of the cavity through invisible channels in the body substance. Most are nourished by absorption through the general surface. They do not possess a nervous system or organs of sense, neither is there any distinct digestive system. In nearly all, a mouth is absent, but it is present in one group. They are nearly all aquatic.

CLASS I.—THE MONERA.

The Monera are the simplest of living beings. They consist of structureless, homogeneous, semi-fluid protoplasm, sometimes so soft and transparent that one can detect it only by its not mixing with the outer water. In this group there is no marked difference in consistence between the inner substance and the outer layer; there is neither mouth, contractile vesicle, nor nucleus. So far as we as yet know, the Monera in no case multiply by sexual reproduction. A portion separates as a bud, or an



Protomyxa aurantiaca (after Haeckel).

individual or a separated part contracts into a round ball, and becomes covered by a transparent layer; the central mass then breaks up into a multitude of grains. Finally, the outer covering bursts, and each of the grains becomes a separate 'moner' of the same species. Notwithstanding their extreme simplicity, the Monera present specific and even generic distinctions. They differ in colour: *Protomyxa aurantiaca,* described by Professor Ernst Haeckel, is bright orange. They differ likewise in habit. *Myxodictyum sociale* of the same author lives in a colony, each of the little round moners being attached to a number of others by spreading sarcode threads.

A large part of the bed of the North Atlantic at great depths is covered with a calcareous sediment composed almost entirely of the broken shells of Foraminifera, the group of Protozoa to be next mentioned. This lime-mud is usually slightly tenacious, as if a little size were mixed with it. On putting it under the microscope, this glairy matter separates into irregular strings, which shew movement. This would seem to be a form of the Monera, even more simple than those which have a definite shape. To this 'Urschleim' of the Atlantic chalk mud, Professor Huxley has given the name of *bathybius.*

CLASS II.—RHIZOPODA.

Gromia is the type. The sarcode body is inclosed in an egg-shaped membranous shell or 'test,' which has a single opening at one end, whence issue long prolongations of its body. These are termed *pseudo-podia* (false feet). They have no limiting wall, but seem just to flow along in the water, and when two come in contact, they flow together. It has no mouth, but obtains its food by throwing out its pseudo-podia, which, when they encounter any substance, such as a minute diatom, gradually close round it, and then pull it into the interior of the shell, where it is digested by the sarcode; and then the indigestible portions are expelled through the opening in the shell.

The *Amœba*, or Proteus animalcule, so called from the facility with which it can change its shape, possesses a nucleus and contractile vesicle, and its pseudo-podia are blunt and club-shaped, but they do not flow together.

Foraminifera :
Gromia.

The *Foraminifera* have a calcareous 'test,' perforated by numerous small apertures, through which pseudo-podia are emitted, or a test made up of sand grains cemented together, and leaving openings for the 'false feet.' Some are simple, as *Lagena*, but most are composite, produced by continuous gemmation or budding, each to the body by which it bud remaining attached was put forth. Some shells have only a single aperture placed at one end, through which the pseudo-podia are protruded. According to the plan of this budding, so will be the form of the composite body produced. In some, the parts are arranged in a straight row; in others, a single row is rolled into a spiral; and in some the parts are in the same plane, or they may form a spire, with a more or less conical form, the first chamber being at the apex. All the chambers communicate together by openings between adjacent chambers. They are marine, and exist in enormous quantities in the bed of the Atlantic, forming the chief part of the 'ooze,' which is composed almost entirely of a species of *Globigerina* (*G. bulloides*).

Foraminifera :
1. Lagena striata ; 2. Textilaria ; 3. Operculina.

The *Polycistinæ* have a silicious instead of a calcareous shell, which is often most beautifully sculptured. They are all minute, and are frequently found in infinite multitudes, forming a coloured cloud on the surface of the sea.

Podocyrtis.

CLASS III.—GREGARINIDÆ

are parasitic in the intestines of some insects, and in the earth-worm. They are probably more allied to some low forms of Entozoa than to the Protozoa.

CLASS IV.—PORIFERA OR SPONGIDEA.

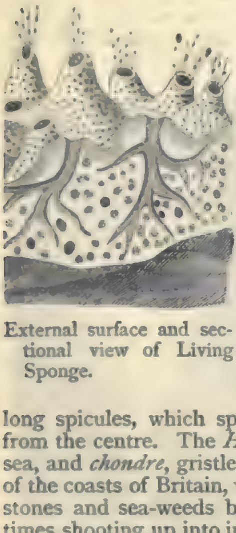
In the sponges, the Protozoa attain their largest dimensions, and their greatest prominence in the economy of the present time. The body consists of sarcode, which is supported by an internal skeleton or framework composed of carbonate of lime, of silica, or of horn, or of a combination of one of the former two with the latter. In the bath sponge, which is the best known example, the skeleton consists of a network of flexible horny fibres alone. When the sponge is taken living from the sea, it is completely filled and covered with the jelly-like living matter. A thin gelatinous membrane, perforated with very small holes, covers the surface, and every here and there rises into a papilla with a large hole at the top. These larger openings are called *oscula*, and they open into a set of channels which divide and branch till they penetrate through the entire substance of the sponge. The pores in the outer wall likewise communicate with the ultimate meshwork of the sponge, and are thus in communication with the channels and the oscula. The channels are lined with cilia—delicate hairs, which, by a perpetual lashing movement, drive the water along the channels ; or they have somewhere in their course chambers lined with cilia. The nutrition and respiration of the sponge are thus conducted : water, with organic food in solution or suspension, and containing air, enters the pores, passes through the tissue of the sponge, and is exhausted by the absorbing sarcode surface. The effete water is then collected into the channels, and urged forward by the cilia till it pours out at the oscula in a stream. True sexual reproduction has not yet been established for sponges : they multiply by the separation of small, oval, ciliated buds, called *gemmules*, which escape along with the water from the oscula.

Hyalonema.

The principal orders of the Porifera are the Calcispongiæ, the Hexactinellidæ, the Ceratospongiæ, the Corticatæ, and the Halichondriæ.

In the *Calcispongiæ* (*calx*, lime, and *spoggos*, a sponge), the sarcode is supported by granular horny matter, mixed with three-rayed needles or spicules of carbonate of lime. These sponges are found frequently

round the coast of Britain, hanging from the under-side of rocks between tide-marks. They are all marine. The second group, the *Hexactinellidæ*, so called from their spicules, which are always silicious, having usually six rays, seem to be confined to the deep sea, and are very abundant there. In this family we have some of the most singular and the most beautiful of natural objects. Venus' flower-basket (*Euplectella aspergillum*), from the seas of the Philippine Islands, is like a graceful horn-of-plenty wrought in an infinitely delicate tissue of spun-glass. *Hyalonema*, the Glass-rope Sponge of Japan, produces, growing downwards from the centre of a small conical sponge, a great wisp of glassy spicules, as thick as knitting-needles, and a couple of feet long, which penetrate the mud, and hold the sponge in its place, like a root. The upper part of this 'glass-rope' is almost always covered with a crust formed of a spreading zoophyte. This is a case of 'commensalism' (Lat. *con*, together; *mensa*, a table), an economical arrangement which is not at all uncommon in nature. Two animals live together habitually, one taking advantage of the excess of food procured by the other by means of currents produced by its cilia or some other like means, and doubtless contributing in some way to the comfort or support of its 'chum.' The bath sponge is the type of the *Ceratospongiæ* (Gr. *keras*, horn), distinguished by their soft flexible skeleton of horn. The sponge of commerce is brought up by divers from water of moderate depth, the finest coming from the coasts of Syria and the Greek Archipelago, the greater number from the Bahamas. The *Corticatæ* (Lat. *cortex*, bark) include the globular sponges, frequent in deep water, with a thick outer bark bristling with long spicules, which spring in sheaves radiating from the centre. The *Halichondriæ* (Gr. *hals*, the sea, and *chondre*, gristle) are the common sponges of the coasts of Britain, very abundantly incrusting stones and sea-weeds below tide-mark, and sometimes shooting up into independent branching tufts or tubes. They are quite frush, and unfit for any use. Their skeleton is composed of a combination of horny granules or fibres, with silicious spicules of diverse and often very elegant forms. Nearly all the Porifera are marine. One genus, Spongilla, or fresh-water sponge, is common in the fresh waters of Britain.



External surface and sectional view of Living Sponge.

CLASS V.—INFUSORIA.

The Infusoria are chiefly microscopic, and are found in all stagnant waters, or in any infusion which has been exposed to the air for some time—hence the name. They do not emit pseudo-podia. They possess a mouth, which leads into a sort of gullet, excavated in the soft gelatinous substance of the body; but this gullet is not continued into a defined stomach or alimentary canal, the organic matter introduced by the mouth passing into, and mixing with the sarcodic substance of the animal. The mouth is generally surrounded by cilia (vibratile hair-like appendages), by which currents are formed in the water, and food brought into it. In the body are a number of contractile vesicles, which pulsate at regular intervals, and may represent a rudimentary heart. *Bursaria* swims freely about by means of the cilia placed all over its surface. The Bell Animalcule, or *Vorticella*, is attached, and remains fixed like a plant. The body is bell-shaped, the opening of the bell being surrounded with a ring of cilia, which, by their vibratile movements, bring food within reach. It is situated on a long stalk, which is capable of spiral contraction. This takes place on the slightest movement or alarm.

Group of Vorticellidæ.

Bacteria, Spontaneous Generation.—If a little weak wine, or a thin syrup of sugar, or an infusion of tea or of meat, be left exposed to the air, it very soon begins to ferment or to putrefy. In doing so, it becomes muddy; and if a drop of the muddy liquid be placed under a microscope, it is found to contain myriads of excessively small living and moving beings, most of which must be referred to the Protozoa, though some are the germs of different kinds of mould (fungi). Two kinds are almost universal in such solutions—minute, transparent, oval bodies, slightly enlarged at each end, called *bacteria;* and very small rods, generally of two joints, called *vibriones.* No structure can be made out in either of these, but they are recognisable and distinguishable from other things, and they have a peculiar vibratile motion. A question has arisen, whether these creatures, which appear everywhere, are all produced from germs of already existing creatures of the same kind, or whether they may originate in the liquid by the uniting of the substances required to form them, which are all contained in the liquid, the product then becoming alive. This latter process has been called 'spontaneous' or 'equivocal' generation. Does life ever originate in such a way? The following considerations seem to render it improbable.

If a ray of sunlight pass through a chink, and traverse a dark room, its path is made evident as a long gray line of motes dancing in the vibrating air. These motes settle down as dust; and if a little of this be magnified, it is found to be mainly broken particles of wool and grains of starch; but it contains germs as well; for if a little dust be shaken into an infusion, we have a crop both of animals and plants at once. Here, then, is a source of germs which is universal. M. Pasteur, a French chemist, has shewn that if a flask be filled with a solution in which, if it were left open, bacteria would abound immediately; and if it be entirely freed by heat from living germs and air containing such, and the neck of

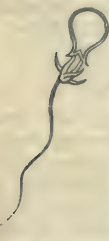
the flask be then closed with a plug of cotton-wool, the liquid may remain for months quite clear.

It is very difficult so to treat a vegetable or animal infusion, and to prevent even one of these infinitely minute and universally distributed particles getting into it during the process. The consequence is, that in many flasks, notwithstanding all precautions, bacteria do appear. One negative in such an investigation is, however, worth a thousand positive observations, and it would seem that the number of negative results is in proportion to the pains taken, and to the skill of the experimenter. All present evidence goes to shew that under no circumstances with which we are acquainted, does any living being arise, except as the progeny of a pre-existing living being of the same kind.

II. SUB-KINGDOM CŒLENTERATA.

The *Cœlenterata* (Gr. *koilos*, hollow, *enteron*, an intestine) have their parts arranged round a central axis in a radiate manner, like the segments of an orange, and they are capable of being split into right and left similar halves. They are thus said to have radial and bilateral *symmetry*. Further, each segment of the body can be divided into two symmetrical halves. They all have a distinct digestive cavity, which always communicates with the outer world by a mouth. In some, the digestive cavity is identical with the body cavity, the stomach being merely hollowed out in the gelatinous body substance; and in others it is distinct, the wall of the stomach hanging as a free sac within the body cavity; but in this latter case there are always free channels of communication between the digestive sac and the general cavity of the body. In the great majority, no circulatory or nervous system is developed.

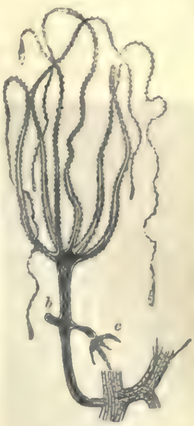
The body-wall is composed of two layers (*ecto-derm*, outer skin, and *endo-derm*, inner skin), which contain a number of peculiar bodies termed 'thread-cells.' These thread-cells consist of an oval bag filled with fluid, within which is coiled a long and extremely slender filament provided with three recurved darts or barbs. On the application of the slightest force to the tensely filled bag, this filament, often several times longer than the bag, is projected outwards, and transfixes and paralyses the prey, while the fluid seems at the same time to exercise a benumbing influence upon it. Distinct reproductive organs are present in all. The *Cœlenterata* are divided into two classes.



One of the larger thread - cells of the Hydra, with its three recurved barbs.

CLASS I.—HYDROZOA.

The digestive cavity is not separated from the body cavity, but is identical with it, and the reproductive organs are on the external surface of the body. *Hydra* is the type. It is usually seen attached to some aquatic plant or twig in our ponds and ditches. It is cylindrical in form and gelatinous in consistence, and usually about half an inch in length. It has at one end an expanded disc, by which it attaches itself to any object; at the other is the mouth, which is surrounded by a circle of arms or tentacles, which move about in all directions in the water. The body is composed of the two layers, armed with *thread-cells*, which are specially abundant in the ectoderm and in the tentacles. Small larvæ and worms are its favourite food. To entrap these, it spreads out its tentacles, moving them gently in the water, to increase their chances. The prey is paralysed by means of the thread-cells, and is pushed through the mouth into the internal cavity, where it undergoes digestion, the indigestible portions being finally expelled through the mouth. It is not permanently fixed, but can detach itself, and move about in the water.



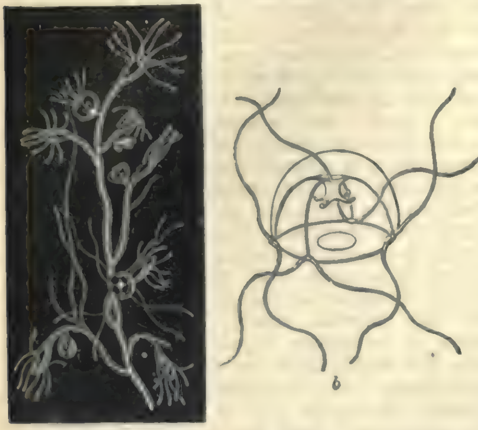
Hydra fusca:
With a young bud at *b*, and more advanced bud at *c*.

Trembley of Geneva shewed that Hydra is exceedingly tenacious of life, and endowed with extraordinary reparative powers. It may be turned inside out and still live, or be cut into pieces, each of which may become a perfect hydra. It increases towards the end of the year by ova; and during the summer months, by buds or *gemmæ*, which sprout from the sides of the parent. At first, the stomachs of the bud and parent are continuous; but they become separated by a constriction, tentacles are formed at the free end, and it then separates as a perfect hydra.

ORDER 1.—*Hydridæ* includes only the genus Hydra. Imagine a hydra going on budding, and the buds remaining attached to the parent—a tree-like arrangement would thus be produced.

ORDERS 2 and 3.—This is almost constantly the case in the second and third orders, *Corynidæ* and *Sertularidæ* (Sea-firs), and the animal is thus composite. It is usually permanently fixed, and is inclosed in a firm but flexible tube, which extends only up to the base of the buds or *polypites* in the *Corynidæ;* but in the *Sertularidæ* forms a little cup for each polypite, into which it can retract itself when alarmed. They are often found on the sea-shore, attached to old shells. The reproductive process in the *Corynidæ* and *Sertularidæ* is certainly very peculiar. At certain seasons, some of the buds become modified in form and structure, so that they assume an appearance not unlike a *Medusa*. To these buds the term *zooid* is applied. After a time, these zooids or Medusa-like buds become detached from the parent stem, and swim about for some period, when there are developed in them the organs of reproduction. So closely do these zooids resemble the true *Medusidæ*, that they were for a long time confounded with them. The ova and spermatozoa of these zooids now unite, and give rise to bodies having the appearance of a flattened disc covered with cilia, by means of which they swim freely about. This disc-like body becomes attached, part of it forming the root by which it is attached, while from its centre there

grows a single polypite, which by budding grows into a form exactly resembling the branched tree-like zoophyte, which gave origin to the Medusa-like bud. This is an example of what Steenstrup called 'alternation of generations,' although it is



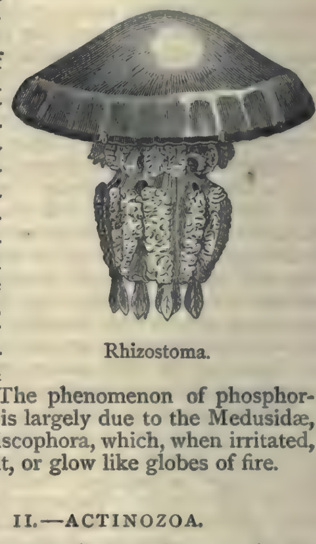
a, Hydromedusarium of ***Bougainvillia superciliaris***; *b*, Young Bougainvillia, or Medusoid bud, liberated from the Hydromedusarium.

not so in reality, there being only one truly generative act—namely, when the ova and spermatozoa of the Medusa-like bud or zooid unite to produce the disc-shaped ciliated body.

ORDER 4.—The *Siphonophora*, represented by *Physalia* (Portuguese man-of-war), *Vellella*, and by a multitude of wonderfully beautiful oceanic-surface forms, such as *Agalma* and *Diphyes*, which frequently swarm in the warmer seas, many of them forming branching feathery organisms several yards in length, and consisting of an infinite number of glassy swimming-belts, feeding polypites, reproductive polypites, and filaments covered with thread-cells, many of their parts relieved and brightened by coloured spots, crimson, blue, or purple. Some have a *float* or inflated bag, which enables them to float on the surface of the ocean. Depending from the under-surface of the animal are a number of thread-like appendages, and a soft flexible stem, to the sides of which are attached numerous buds or polypites. These also reproduce themselves by Medusa-like buds, like the *Sertularia*.

ORDER 5.—The true *Medusidæ* have a swimming-bell, like an umbrella, composed of a jelly-like material. A single polypite is suspended from the centre of the concavity of the bell; and, running inwards from its margin is a veil, perforated in the centre by an aperture, through which water is admitted into the interior of the bell, and is again expelled by its rhythmical contractions, so that the animal moves in a direction opposite to that in which the water is expelled. Four canals, radiating from the centre, run in its walls, and are joined at the circumference by a circular canal. Suspended from the margin of the bell is a number of tentacles, and on it are several coloured spots, which are supposed to represent rudimentary eyes. These Medusæ produce animals exactly resembling themselves.

ORDER 6.—*Discophora*. In the interior of old shells may be found an animal closely resembling Hydra, but sexless. It is called *Hydra tuba*. At certain seasons, a number of transverse markings may be seen upon a cone-like appendage growing from the free end of the hydra, which gradually deepen into annular constrictions, so that it looks like a pile of saucers. Each segment is thus a transverse segment of the cone-like body projecting from the free end of the hydra tuba. Each develops tentacles, and becoming detached, grows into a *hooded-eyed* Medusa. This, when perfectly developed, consists of an umbrella or swimming-bell, with one or more polypites suspended from its concavity. It has eight radiating canals, whose branches anastomose with each other; but it has no veil. It has a number of tentacles suspended from the margin of the umbrella, and upon it are coloured eye-spots, and small cavities containing a fluid with crystals of carbonate of lime. These last are supposed to represent organs of hearing. Both of these are covered over by a fold of membrane like a hood, and hence the name 'hooded-eyed' Medusæ. They are often of enormous size, and are commonly called *jelly-fish* or *sea-blubbers*. They are represented by such forms as *Rhizostoma* and *Pelagia*. These produce ova, which again, in turn, give rise to hydra tuba, affording another example of the so-called 'alternation of generations.' The phenomenon of phosphorescence of the sea is largely due to the Medusidæ, and some of the Discophora, which, when irritated, emit sparks of light, or glow like globes of fire.



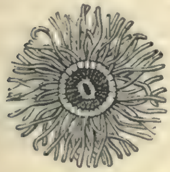
Rhizostoma.

CLASS II.—ACTINOZOA.

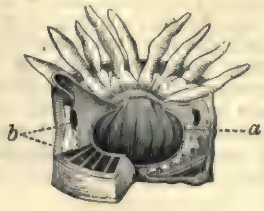
The digestive sac is distinct from, and suspended in, the body cavity, communicating freely with it by an opening below. The space intervening between the stomach and the body-wall is called the 'peri-visceral space,' and is divided into a series of chambers by vertical partitions, to the faces of which the reproductive organs are attached.

Actinia is the type (*aktis*, a ray). The body is short, and of fleshy consistence, attached at one end to a rock, and having at the other the mouth, surrounded by several rows of tentacles, which, from their arrangement and colour, like that of a full-blown many-petalled flower, have obtained for this animal its common name of sea-anemone. The mouth leads into a stomach, opening at its lower end into the peri-visceral cavity, which is divided by vertical partitions, having the reproductive organs attached to them. They feed upon shell-fish and other marine animals, which they draw into the mouth by the tentacles, disgorging shortly afterwards the shells and other indigestible parts. They are very sensitive to light, and expand or

close their tentacles according to the fineness of the day. When the feelers are drawn in, the apertures from which they proceed close like the



Actinia seen from above.



Section of Actinia : *a*, cavity of stomach ; *b*, surrounding chambers.

mouth of a purse, and the animal appears like a simple fleshy tubercle adhering to the rocks.

ORDER 1. *Zoantharia.*—The *Zoantharia* have the tentacles numerous and simple, while the radiating partitions are in multiples of *five* or *six*. They are represented by *Actinia* or Sea-anemone, many species of which occur along our shores. Some forms, however, are supported by a structure called a *coral*, which is composed of calcareous matter, or of horny matter, or partly of both. In one group this coral consists of a solid rod or axis, quite smooth on the surface, and presenting no appearance of cups, and merely acting as a support, over which the soft tissues of the animals are stretched. To a coral quite smooth and devoid of cups, the term *sclero-basic* is applied (Gr. *scleros*, hard, and *basis*, pedestal). The Black Coral (*Antipathes*), which is so much prized, has a sclero-basic coral, composed of horny and calcareous matter, forming a smooth, solid, branching structure, over which the tissues of the animal are stretched. In another group, the tissues of the animal are more or less completely calcified, by the deposition of particles of carbonate of lime in their structure. Such a coral is called a *sclero-dermic coral* (*scleros*, hard, and *derma*, skin), and it can at once be distinguished from the former by the presence of the calcified cups for the polyps. Like the animal which produces it, a sclero-dermic coral may be simple or compound. Thus *Carophyllia* is a simple coral, and consists of a calcified cup or *corallite*. The calcified boundary wall of this conical simple corallite is called the *theca*, the lower part of which is divided by a series of radiating calcified vertical partitions (*septa*) into chambers or *loculi*, while the upper part is vacant. Many of these septa run from the interior of the theca, and meet in the centre, forming a *columella* or axial support.

Caryophyllia borealis.

In a compound coral the various cups are united by calcareous matter, the whole exactly resembling in form the animal which secreted it. As examples of compound sclero-dermic corals may be cited the Brain Corals (*Meandrina*), and Star Corals (*Asteriadæ*). Amongst simple sclero-dermic corals, the following are found off the coast of Britain in deep water—*Lophohelia prolifera*, *Amphihelia ramea*, *Allopera oculina*, and *Caryophyllia borealis*.

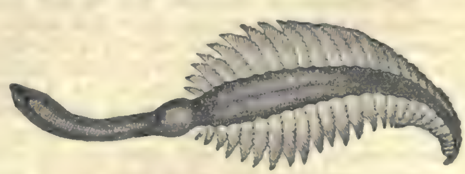
Extensive reefs and many islands in the Pacific Ocean, Indian Sea, and throughout Polynesia, are composed of coral, the product of these minute polypes. Darwin has classified coral reefs into (*a*) atolls, (*b*) barrier reefs, and (*c*) fringing reefs.

Fringing reefs skirt continents or surround islands. The channel between them and the land is shallow, and outside the reef there is no great depth of water.

Barrier reefs may encircle islands or skirt continents. The channel between the land and the reef is navigable, and outside, the soundings indicate enormous depths. The reef on the north-east of Australia is 1250 miles long, and from 10 to 90 in breadth, and rises from its seaward edge in some places free 1800 feet.

Atolls are circular coral reefs inclosing an expanse of water, which is called a 'lagoon.' The circle has breaks in it here and there, and is generally highest towards the windward side, against which the waves are continually dashing with great violence. The coral-producing polypes cannot exist in fresh water, hence the breaks in the circle where a stream had poured its waters into the ocean; neither can they exist at a depth of over 80 fathoms, or withstand the heat of the sun's rays. A mean winter temperature of not less than 66° is necessary for their existence. When a reef, by the gradual elevation of the land upon which it is placed, has reached the surface of the water, sand, shells, fragments of coral broken off by the waves, and other substances begin to accumulate, and cocoa-nut trees often grow while the waves still wash their roots. Further accumulations from the ocean, with decayed leaves, stems, &c. gradually convert the reef into fertile land. Mr Darwin shewed that a fringing might be converted into a barrier reef by the gradual sinking of the land on which the reef is built, the coral polypes gradually building upward; and by a further subsidence, a barrier reef might be converted into an atoll. This accounts for the great depth of some of the coral reefs that exist in the Pacific Ocean.

ORDER 2. *Alcyonaria*—characterised by having the tentacles fringed, and the parts in multiples of *four*—includes *Alcyonium*, or 'dead-man's fingers,'



Pennatula.

so called from its flabby appearance when seen in the fisherman's net. It is a composite animal, and is studded all over with little pits, from which polypes protrude. Its body contains a few spicules, and is traversed by a system of canals, which

connect the various polypes together. *Pennatula*, the Sea-pen, has one end of the axis, which is supported by a sclero-basic coral, fixed in the sand in the sea-bottom. From this axis, lateral branches are given off, upon which are placed the polypes. Its colour is reddish yellow, and when irritated, it shews phosphorescence. In *Gorgonia* (Sea-shrub), the coral is branched, horny, and sclero-basic. The Red Coral of commerce (*Corallium rubrum*), whose sclero-basic coral is so much admired for its fine colour and for ornamental purposes, has a smooth and branched tree-like form, about one foot in height, and is about the thickness of the little finger. It is chiefly obtained from the Mediterranean, and is largely exported to India.

ORDER 3. *Ctenophora*—are free-swimming ocean forms, which never develop a coral. They are gelatinous-like bodies, spherical in form, very delicate, and transparent. Eight bands covered with cilia run from pole to pole. By the motion of these cilia, the animal moves along. A trace of a nervous system has been discovered in some forms, *Beroe pileus*, which is like a globe of jelly, about half an inch in diameter, forms part of the food of the whale, and is often seen in the English Channel.

III. SUB-KINGDOM ECHINODERMATA.

The *Echinodermata* (*echinos*, urchin, and *derma*, skin), or Spiny-skinned Animals, are so called because they have a crustaceous or coriaceous covering generally armed with tubercles or spines. They have their parts arranged radially, but they also exhibit bilateral symmetry. The alimentary canal is completely shut off from the body cavity. The integument covering the animal is more or less completely calcified by the deposition of calcareous particles. In these animals there exists a peculiar system of tubes, called the *ambulacral system* (*ambulo*, I walk), because they are used for the purpose of progression. The nervous system consists of a gangliated nervous cord surrounding the commencement of the gullet, and sending branches which radiate outwards parallel with the ambulacral tubes. A blood-vascular or circulatory system is also present. In their mode of reproduction, the members of this group exhibit some very peculiar phenomena. The embryo is at first free, swimming, and ciliated, and is provided with distinct digestive organs, which do *not* become converted into the corresponding structures of the adult. This embryonic form has been called a *pseud-embryo* (false-embryo), bearing no resemblance to its parent; so much so, that the embryo of *Echinus* was at one time described as a distinct animal under the name of *Pluteus*. Only a part of this embryo is converted into the adult Echinoderm, the remainder entirely disappearing. The adult form is, as it were, a sprout from a particular part of this pseud-embryo. This sprout goes on developing a distinct mouth, digestive and other organs, until it exactly resembles the adult form which gave rise to the Pluteus.

It contains several orders, two of which, the *Blastoidea* and *Cystoidea*, are entirely extinct. Representatives of these two orders, such as *Pentremites* of the coal, and *Echinosphærites* of the Silurian rocks, flourished during the Palæozoic age.

ORDER 1. The *Crinoidea*, or sea-lilies, are fixed during the whole or part of their existence to the sea-bottom by a jointed and flexible stalk. They consist of a series of plates articulated together, forming a central cup or disc. From the edge of this cup there spring five arms, which bifurcate, and thus form ten beautifully fringed arms. Running along the inside of the arms is a furrow, covered in by the skin of the disc, and from which are protruded the ambulacral feet. Amongst the permanently fixed and best-known forms is the *Pentacrinus Caput-medusæ*, or Medusæ-head Star of the West Indies. More recently, several

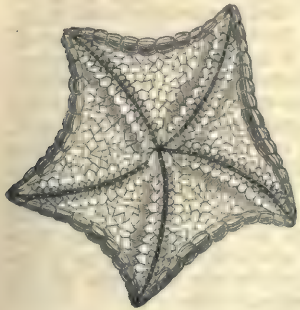
Pentacrinus Caput-medusæ.

new genera have been discovered, since deep-sea exploration and dredging have been suggested and carried out, such as *Rhizocrinus*, which was found off the coast of Norway. In *Comatula*, or the Feather-star, the adult form is free, whilst the young, which was formerly described as a distinct animal, is fixed. The *Crinoidea*, however, were much more abundant during the Carboniferous period, where the mountain limestone is largely composed of the stalks of the forms that flourished there. The individual joints of the stem, when separated, are known as St Cuthbert's beads. In the Muschelkalk, one of the secondary Triassic rocks of Germany, a very pretty form, the *Encrinus liliformis*, or stone-lily, is specially abundant, and is very well known.

ORDER 2. The *Ophiuridea*, represented by the 'Sand-stars' (*Ophiura*) and 'Brittle-stars' (*Ophiocoma*), are star-fishes having five slender arms radiating from a small central disk, on the lower surface of which the mouth is placed. The arms do not contain any prolongation of the viscera, but consist of a central series of ossicles united by powerful muscles, and of an external mailing of several series of plates of the perison. The ambulacral vessel runs along the lower surface of the arm, and gives off at each joint a pair of long conical tubular appendages, without suckers, which are used for locomotion and respiration. There is no excretory opening, the indigested matter being thrown out from the mouth.

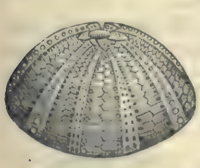
ORDER 2. *Asteroidea*.—The common *Asterias*, or Star-fish, which may be taken as the type of

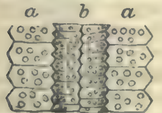
this order, is covered with a tough leathery skin beset with prickles. The animal has the form of a star with five or more rays radiating from a central disc. In the middle of the under surface of the disc is situated the mouth, opening into an intestine, which sends prolongations into each ray. In some forms there is no anus present, so that the indigestible portions of the food have to be ejected through the mouth, as in the common sea-anemone. If the prickly skin be removed, it is seen that it is supported by a series of plates, beautifully jointed together. On the under surface of each ray, the plates exhibit a series of perforations, through which, in the living state, the ambulacral feet can be protruded. They are found in almost all tropical and European seas, and some species are found as far north as Greenland.



Asterias tessellata (*Asteriadæ*).

ORDER 4. *Echinoidea.*—The members of this order are commonly known as Sea-urchins or Sea-eggs. The body is somewhat globose in form, and composed of a series of plates jointed together. In the Echinus, we observe two orifices situated at the two poles of this globe; the larger of these orifices, directed downwards, is the mouth; at the smaller one, placed superiorly, the intestine terminates. The mouth is furnished with a curious apparatus of teeth, known as 'Aristotle's Lantern,' worked by a powerful set of muscles attached to the edge of the shell near the mouth. By the action of the teeth the food is ground down before it passes into the intestine, which takes a couple of turns round the shell before its termination. Round the second orifice of the shell are disposed the ovaria, which are very largely distended with eggs at some seasons, and are eaten under the name of *roe of the sea-egg*. On looking at the *Echinoidea* in the living state, we see that most of them are covered with spines of considerable size. Moreover, these spines are movable at the base, which is hollowed out into a little cup, which fits on a rounded projection from the shell, thus forming a complete ball-and-socket joint. These spines are connected to the shell, and are moved by the skin which covers the latter. On looking at the shell of an Echinus, it is seen to be composed of twenty rows of plates, generally hexagonal in form, accurately fitted to each other, running from pole to pole. They are so arranged that there are ten alternating zones, each zone being composed of two rows of similar plates. There are five double rows of large plates, which are imperforate, and studded with tubercles. These are the *inter-ambulacral* areas. The other five double rows (*ambulacral areas*) alternate regularly with these, and are composed of small plates, which are perforated by numerous apertures for the protrusion of the *ambulacral feet.*





Shell of Echinus:
a, inter-ambulacral plates;
b, ambulacral plates.

These feet are distended by water admitted from without through a specially modified plate, called the madreporiform tubercle, which admits it into the sand-canal, a straight tube filled with peculiarly shaped spicules, which finally opens into a ring-like vessel surrounding the œsophagus, and sending off tubes in a radiate manner, from which the ambulacral feet spring. When water is admitted into these feet, they become distended, and are protruded through the ambulacral apertures. These feet are provided with a small sucker, by which they can adhere to the rocks, thus enabling the animal to move along. Attached to and communicating with the ring-like vessel surrounding the œsophagus, are two little sacs or bags, called *Polian vesicles*, which act as reservoirs for the water, so that the ambulacral feet can be protruded at will. The spines are most numerous in the inter-ambulacral areas. In order to provide for the growth of the shell, there is interposed between adjoining plates a thin membrane, by the calcification of which the plates increase in size at their edges. These animals are found on sandy shores, and on the bottom of the sea, creeping along with their feet. Their food is of a mixed character, consisting of crustacea and sea-weed. In some forms, as *Spatangus* (Heart Urchin), the shell is ovoid or heart-shaped, and the mouth is eccentric. In these cases, the dental apparatus is generally imperfectly developed.

ORDER 5. The *Holothuridea*, the last and most highly organised Echinoderms, are destitute of spines or prickles, and have the body shaped like a cucumber, and inclosed in a highly elastic skin. They are commonly known by the name of *sea-cucumbers.* Some of the species are edible, and, when dried, are the *trepang* of commerce. By the Malays, they are diligently sought after for the supply of the Chinese market.

IV. SUB-KINGDOM ANNULOSA.

The *Annulosa*, or Ringed Animals, have their segments arranged, one behind the other, from before backwards. They exhibit bilateral symmetry, each segment being also symmetrical. The alimentary canal, which is present in all except a few internal parasites, is distinctly shut off from the body cavity. In most, a blood-vascular system is present, and is always placed dorsally. In the higher orders, the nervous system consists of a double symmetrical cord, placed along the ventral surface of the animal, and having upon it small swellings composed of nervous matter, and termed *ganglia*, two ganglia corresponding to each segment. These ganglia give off branches to their respective segments. Anteriorly, the gullet is surrounded by these nervous cords, so that it passes through a ring of nervous matter.

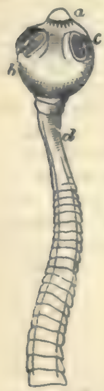
The *Annulosa* are divided into two principal divisions: I. Vermes, and II. Arthropoda.

DIVISION I.—VERMES

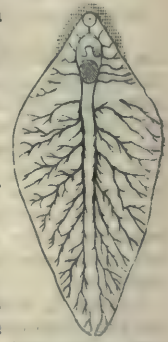
(Worms), in which the division of the body into longitudinally arranged segments is not apparent, or but imperfectly marked; and there is an absence of appendages jointed or articulated to the body.

CLASS (A). *Platyelmia*, or Flat-worms, are usually flattened and ovoid in form, and the segmentation of the body is not distinct. The nervous system consists of a pair of ganglia, situated at the anterior extremity of the body, from which filaments arise and pass backwards. Some live in the interior of other animals, and are parasitic; while others are covered with cilia, and swim freely in the water.

ORDER 1. *Cestoidea*—including the family of the *Tæniadæ*, or Tape-worms, which are parasitic in the intestinal canal of warm-blooded vertebrata. The mature worm is ribbon-like, and consists of many joints or segments, which resemble each other. The anterior segment, or *head*, has a circle of hooks and suckers by which it is enabled to fix itself to the intestinal canal of its 'host.' The various segments are produced by a process of budding from the head posteriorly, so that the oldest and most mature are farthest removed from it, each new bud being formed between the head and the last-formed segment. As neither mouth nor digestive system is present, the animal is nourished by absorption through the soft skin of the body. Running down along each side is a vessel, which communicates with its fellow by a branch at the posterior part of each segment. This is described as a water-vascular system, but in none of the Vermes is it ever used for purposes of progression. Each segment, except the head, is provided with male and female sexual organs. The female organ consists of a branched tree-like tube, occupying nearly the whole of each segment, which opens along with the male duct at the apex of a little elevation placed on the margin or surface of the segment. The development of these animals presents some most remarkable phenomena. Sexually mature segments can only be formed in the intestinal canal of a warm-blooded vertebrate; but the development of an embryo cannot go on unless the ova are introduced into the intestinal canal of some animal other than the one in which the mature segments were produced; so that the segments with ova have to be expelled from the bowel. The joints, after expulsion from the bowel, decompose, and liberate the ova, which, when swallowed by another warm-blooded vertebrate, give rise to an embryo which is provided with spines suited for boring. With these it perforates the wall of the stomach, and reaches some solid organ, such as the liver or brain, where it develops for itself a bag or cyst, and is said to become *encysted*. In this condition it is composed of a 'head' furnished with hooklets, and a vesicle filled with fluid at its posterior extremity; but it has no generative organs. These are the so-called *cystic worms*, whose presence in the brain of sheep gives rise to the disease called 'the staggers.' Unless the organ, such as the liver or brain, containing these cystic worms is swallowed by some other warm-blooded vertebrate, they undergo no further development. When swallowed, their vesicle disappears, and buds are given off from their posterior extremity, which develop organs of reproduction, and constitute the segments of the adult worm. The ordinary tape-worm met with in the intestinal canal of man in this country is *Tænia solium*, which sometimes measures several yards in length. The cystic form of this species is called *Cysticercus cellulosæ*. It is found in the muscles of the pig, constituting what is known as *measly* pork. If a portion of this is eaten by man, the cystic form develops itself in his intestinal canal into a tapeworm. Another tape-worm common in man is the *Tænia medio-canellata*, which is derived from the 'measles' of the ox.



Tape-worm: Head, neck, and upper joints of *Tænia solium* magnified; *a*, the circle of hooks; *b* and *c*, two of the sucking discs; *d*, the neck.



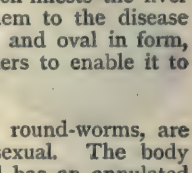
Fluke-worm (*Distoma hepaticum*).

ORDER 2. *Trematoda*—are parasitic, and include the *Distoma hepaticum*, or 'fluke,' which infests the liver of sheep, and gives rise in them to the disease called 'rot.' The body is flat and oval in form, being furnished with two suckers to enable it to adhere to its host.

CLASS (B). *Nematelmia*, or round-worms, are nearly all parasitic and unisexual. The body is rounded and elongated, and has an annulated appearance.

ORDER 3. *Gordiacea*, or hair-worms, distinguished by their great length, sometimes make their appearance in enormous numbers in particular places, and give rise to the phenomenon of 'worm-showers.'

ORDER 4. *Nematoda* are free or parasitic. Type *Ascaris lumbricoides*, or round-worms of the human subject, is elongated and cylindrical in form, and has a wrinkled appearance. An alimentary canal and distinct anus are present. The sexes are distinct. The nervous system is in the form of a ring encircling the gullet, giving branches forwards and backwards. The Thread-worms (*Oxyuris*), which are so troublesome to children, belong to this group. The Guinea-worm (*Filaria medinensis*) lives in the cellular tissue under the skin chiefly of the legs. It is often several feet long; and is common in tropical Africa.



Trichina spiralis spirally coiled within its cyst. (From Küchenmeister's *Parasites*.)

In the muscles of the human subject, coiled up

within a cyst, has been found the *Trichina spiralis.* This parasite has appeared most frequently in Germany, and its presence is ascribed to the use of pork, raw or imperfectly cooked, in which the Trichina exists, for it also inhabits the muscles of the hog as well as of the human being. When thus encysted, it never develops sexual organs, but must be again swallowed by a warm-blooded vertebrate before it can reproduce itself. Its presence in the muscles gives rise to the painful disease called Trichiniasis. The non-parasitic forms are represented by the *Anguillulidæ*, which are little eel-like worms. One species, *A. tritici*, causes the disease termed 'cockle' in wheat. Another, *A. aceti*, is met with in stale vinegar; whilst a third, *A. glutinis*, or 'paste-eel,' is met with in paste that is turning sour.

CLASS (C).—*Rotifera*, or wheel-animalcules, represented by such forms as *Hydatina* and *Floscularia*, are microscopic aquatic animals, having an elongated slightly segmented body, and carrying at its anterior end a ciliated disc, which, by creating a vortex, carries to their mouths any food which may be floating in their neighbourhood. They possess a mouth and intestinal canal; and a water-vascular system is present. They are very tenacious of life; so that, if they are dried until they are quite brittle, on the return of moisture, they unfold their wheel-like organs, and are as active as before.

CLASS (D).—In the *Annelida*, the segmentation of the body is generally distinctly recognisable, and all the segments usually resemble each other, except those at the two ends. If a segment carries lateral appendages, these are never articulated to the body. The digestive canal runs straight through the animal from the mouth to the anus. A system of canals exists, which contain a coloured fluid, usually red or green, which is supposed to represent the vascular system. The nervous system consists of a double gangliated cord placed ventrally, which encircles the gullet anteriorly.

This class includes two sections: 1. *Abranchiata*, including the Leeches and Earth-worms, in which there is no external respiratory organs or branchiæ. 2. *Branchiata* comprises the Tube-worms (*Tubicola*) and the Sand-worms (*Errantia*), in which branchiæ are present.

ORDER 1. *Discophora*—for example, the leeches, which possess an adherent sucker at their anterior and posterior extremities, which they use for locomotion. They have no lateral appendages. The body has well-marked annulations. They are aquatic, living chiefly in fresh water; but a few are marine. The mouth of the Medicinal Leech (*Sanguisuga officinalis*) is furnished with teeth arranged in a tri-radiate manner. Each tooth has a serrated edge, and when the teeth are worked backwards and forwards, they inflict the characteristic leech-bite when these animals are applied to the skin. Respiration is performed by the skin or by involutions of the integument. Leeches are hermaphrodite, but they are incapable of self-impregnation. They are very common in the south of France, Bohemia, Hungary, and Russia. The Horse-leech (*Hæmopis sanguisorba*) is common in Britain; it is larger than the medicinal leech, but its teeth are blunt, and it is useless for medical purposes. In Ceylon, the Land-leech is very troublesome to men and quadrupeds who have occasion to walk through the grass. They insinuate themselves under the finest stockings, and

Horse-leech (*Hæmopis sanguisorba*).

suck the blood of their victims; so that the coffee-planters are forced to wear *leech-gaiters* of closely woven cloth for protection.

ORDER 2. *Oligochæta*—comprise the Earth-worms (*Lumbricidæ*). Their organs of locomotion consist of a double row of bristles attached to the under surface of the body. They are all hermaphrodite. The Common Earth-worm (*Lumbricus terrestris*) is of great importance to the agriculturist, by continually bringing the deeper portions of the soil to the surface. Besides they are useful as food for birds and fishes, and their value as bait is well known to every angler.

ORDER 3. *Tubicola*—are all marine, and they invariably form for themselves a tube or case into which they can retract themselves. This tube may be composed of particles of sand, which the animal glues together with mucus, as in the genus *Terebella*, or it may be of a horny, or even of a calcareous nature, formed from matter excreted by the animal. There is no organic connection between the tube and its inhabitant, for the creature can be easily drawn out of it. The organs of respiration consist of a tuft of plume-like ciliated organs situated on the head. These are often beautifully coloured, from the coloured fluid, representing the blood, which circulates in them. The genus *Serpula*, which forms irregularly twisted

Serpula contortuplicata.

calcareous tubes attached to shells and stones, is very common along our coasts.

ORDER 4. *Errantia*—are free-swimming annelids, which do not develop a tube. The segmentation is distinctly pronounced, and the anterior extremity of the body is marked out as a head, which is usually provided with eyes. It

includes the *Arenicola piscatorum*, or Lob-worm, the *Nereis* (Sea-centipede), and the Sea-mouse (*Aphrodite*). The respiratory organs are in the form of tufts of branchiæ, which are placed along the back or sides of the creature. The back of the Sea-mouse is covered by a series of membranous plates, protecting the bristles of the feet, which exhibit beautiful iridescent metallic colours.

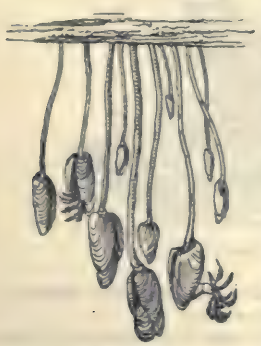
DIVISION II.—ARTHROPODA,

in which the division of the body into segments is well marked, and *jointed appendages articulated to the body are present*. Most of the segments and appendages are protected by an outer covering, often composed of chitine, which forms a sort of exo-skeleton. The appendages are hollow, and the muscles are prolonged into their interior. The nervous system exhibits the well-marked Annulose type. Respiration is performed differently in the different groups. The vascular system, when present, is always placed dorsally.

The *Arthropoda* (Gr. *arthros*, a joint, and *pous*, a foot) are divided into four great classes—namely, the *Crustacea*, the *Arachnida*, the *Myriapoda*, and the *Insecta*.

CLASS I. *Crustacea*.—In a typical crustacean, the body consists of twenty-one segments, seven of which belong to the *head*, seven to the *thorax*, and seven to the *abdomen*. But sometimes the head segments unite with those of the thorax, and form a *cephalo-thorax*. Some of the segments may be suppressed. Some or all of the segments are provided with a single pair of articulated appendages. The animals are fitted for life in water, and they therefore breathe by gills, or by the general surface of the body. The head carries two pairs of jointed antennæ or feelers. The appendages for locomotion are borne by the thoracic segments, and usually by those of the abdomen also. The body is protected by a calcareous or horny covering or 'crust.' They all undergo a series of metamorphoses or changes before they reach the mature condition.

ORDER I. *Ichthyophthira* and *Rhizocephala*, or the *Parasitica* of Lamarck—in their embryonic condition are furnished with eyes and antennæ, and swim freely about; but the adult is parasitic on the eyes and gills of fishes, to which it adheres by a suctorial mouth.



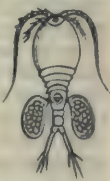
Barnacle.

ORDER 2. *Cirripedia* (Lat. *cirrus*, a tendril, and *pes*, a foot)—represented by the Acorn-shells and Barnacles. In the adult condition, they are permanently fixed, and are usually seen attached to rocks, pieces of floating timber, or the bottoms of ships. Several of the head segments are so modified as to form a multivalve shell, inclosing the animal, from which it can protrude itself. The thorax is provided with six pairs of ciliated limbs, which, being protruded through the opening in the shell, and creating currents in the water, bring food to the animal. The embryo is a free-swimming form, which is provided with one eye, has two pairs of antennæ, and six limbs, which it uses for swimming. In the barnacles (*Lepadidæ*), the animal is fixed by a long stalk or peduncle; while the acorn-shells (*Balani*) are sessile, having no stalk.

SUB-CLASS *Entomostraca*.—Those crustaceans which possess more or fewer than fourteen thoracico-abdominal segments are included under the sub-class *Entomostraca*, which includes five orders.

ORDER 3. *Ostracoda*—for example, the genus *Cypris*, which abounds in every pool of fresh water. It is a small animal, protected by a shell composed of two valves, which it can open and shut at will. It has two or three pairs of feet, and the branchiæ or gills are attached to the posterior jaws, which surround the mouth. In a fossil state, their shells are found abundantly in the Wealden rocks of England, in the Carboniferous Limestones, &c.

ORDER 4. *Copepoda*—for example, *Cyclops*, one of the 'Water-fleas,' which is common in all our ponds and ditches. It is of small size, and the head and thorax are protected above by a structure called a *carapace*. It has a single large eye, placed anteriorly, and two pairs of antennæ. Five pairs of feet are present, and are used for swimming.



Cyclops vulgaris, magnified.

ORDER 5. *Cladocera*—represented by *Daphnia pulex*, another of the Water-fleas. The head is distinct, and has a single eye, and the remainder of the body is inclosed in a shell.

ORDER 6. *Phyllopoda* (*phyllon*, a leaf, and *pous*, a foot)—includes the genus *Apus* and the Fairy Shrimp, in which the body is protected by a carapace. They have always more than sixteen feet, which carry the gills; and the eyes are well developed.

An order, the *Trilobita*, now entirely extinct, was probably allied to the *Phyllopoda*. The body was covered by a chitinous shield, consisting of a cephalic shield, a variable number of body-segments, and a tail with the joints more or less anchylosed, the whole shewing a division into three longitudinal lobes, hence the name. The eyes were sessile and compound, and the number of facets in the lens of one species numbered 6000. They were entirely confined to the Palæozoic rocks, and over 200 species have been described from the Silurian rocks alone.

Asaphus tuberculatus.

Limulus Polyphemus.

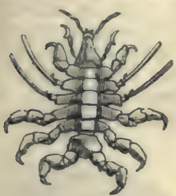
ORDER 7. *Xiphosura* (*xiphos*, a sword, and *oura*, a tail)—represented at the present day by

the King Crabs or Molucca Crabs (*Limulus*), which sometimes measure two feet in length. The dorsal surface of the cephalo-thorax is covered by a large convex shield, upon which are placed the eyes. The abdomen is also protected by a second shield, which terminates in a long sword-like process. The mouth, placed on the under surface of the head, is surrounded by six pairs of appendages, whose bases are suited for masticating food, their extremities being clawed. Attached to the abdomen are six pairs of appendages, which carry the gills.

SUB-CLASS *Malacostraca* includes those crustaceans which have a *definite* number of body-segments. It includes

DIVISION (A).—EDRIOPHTHALMATA,

in which the eyes are not situated on stalks, and the body is unprotected by a shield. It comprises three orders.


Cyamus Ceti.

ORDER 8. *Læmodipoda* (*laimos*, the throat, *pous*, a foot).—The head is confluent with the first thoracic segment. These segments support the four anterior feet, so that they seem to be under the throat—hence the name. The abdomen is rudimentary. The most common is the *Cyamus Ceti* (or Whale-louse), which is a small animal parasitic on the body of the whale.

ORDER 9. *Amphipoda* (*amphis*, on both sides, and *pous*, a foot).—The respiratory organs are attached to the thorax; the abdomen is well developed, and composed of seven segments. The first thoracic segment is distinct from the head, and the thorax carries seven pairs of limbs, some of which are directed forwards, some backwards. The species best known in Britain is the *Talitrus locusta* (Sand-hopper), which burrows in the sand, and seldom enters the water.

ORDER 10. *Isopoda* (*isos*, equal, and *pous*, a foot).—The head is distinct. The feet are alike, and adapted for locomotion and grasping. The most familiar is the *Oniscus* (Wood-louse).

DIVISION (B).—PODOPHTHALMIA.

The eyes are supported on movable stalks, and the cephalo-thorax is protected by a carapace. It includes two orders.

ORDER 11. *Stomapoda* (*stoma*, a mouth, and *pous*, a foot).—They are all marine. The Locust-shrimp (*Squilla*), which is common in the Mediterranean, is a well-known form, and is about seven inches long. The gills are naked, and adhere to five pairs of feet, which are abdominal in position, and leaf-like in form. Some of the anterior appendages are transformed into powerful, prehensile feet, but they are never used for nipping, while the posterior feet are used for swimming.

ORDER 12. *Decapoda* (*deka*, ten, *pous*, a foot).—It includes the stalked-eyed crustaceans, whose cephalo-thorax is protected by a strong calcareous carapace, which exhibits no trace of segmentary division. The gills lie in a cavity on each side of the cephalo-thorax. The thoracic legs are ten in number, hence the name. It includes a great number of species, most of which are useful for food, and they are by far the most highly organised of all the Crustaceans. According to the development of the abdomen, three sub-orders are formed.

Sub-order 1. *Macrura* (*makros*, long, *oura*, a tail), or Long-tailed Decapods—including the Lobster, Prawn, Cray-fish, and Shrimp. The abdomen is well developed, and ends in a powerful fan-shaped swimming organ. The head carries the compound eyes, placed on long movable stalks. Two pairs of antennæ are also present. The mouth is on the under surface of the head, and some of the appendages are so modified as to form powerful claws or nipping organs. The abdominal segments carry swimming organs. The heart is well developed, and is situated dorsally. The nervous system is well pronounced, and is situated ventrally.

Sub-order 2. *Anomura* (*anomos*, irregular, and *oura*, a tail).—The abdomen is not so long as in the Macrura, nor so short as in the next order. To this order belongs the Hermit Crab (*Pagurus*), whose abdomen is quite soft. They are remarkable for living in the deserted shells of mollusca, exchanging a less for a larger as they increase in size. It fixes itself in the shell by a sucker and rudimentary feet. Well-developed feet are present, the anterior pair being usually transformed into formidable nippers. They feed upon dead fish. When alarmed, they retire within the shell, and close the aperture with their claws.


Hermit Crab in shell.

Sub-order 3. *Brachyura* (*brachys*, short, *oura*, a tail), or Short-tailed Decapods—have the tail short, and folded under the large cephalo-thorax. The Large Edible Crab (*Cancer pagurus*) is the type. The legs are of moderate length, but the claws are large. At low tide in summer, it is found in holes of rocks. The Small Edible Crab (*Carcinus mænas*) is another well-known British species. The Land-crabs (*Gecarcinus*)—called also violet crabs and white crabs, from their colour—are natives of the West India Islands and South America. They have an arrangement of leaflets for retaining moisture for their gills. They live in mountainous places, far from the sea, which they visit once a year to deposit their eggs. During the day, they retire into their burrows, which they make in the earth, roaming about at night in search of food. The Common Crab, on coming out of the egg, has a long tail, with several curious spine-like processes attached to it, and was formerly described as a distinct animal under the name of *Zoea*. It undergoes curious metamorphoses before it reaches the adult condition.

CLASS 2. *Arachnida*—are annulose animals, whose respiration is aërial. The head is confluent with the chest, thus forming acephalo-thorax, and the abdomen never carries jointed appendages. Eight legs are present, but the antennæ as such are absent. It includes the familiar group of Spiders and their allies.

SUB-DIVISION (A). *Trachearia* (*trachea*, the windpipe)—includes such spiders as breathe by tracheæ. These tracheæ are tubes which ramify through the tissues of the body, and open on the surface by distinct apertures called *stigmata*. The tubes are kept pervious by a spiral elastic filament, which is coiled up within them. The *Trachearia* have never more than four eyes.

ORDER I. *Podostomata*.—They are all marine, and are commonly known as 'Sea-spiders.' Some of them, as *Nymphæ*, are found amongst the stones and weeds on the sea-shore, while others, such as *Pycruogonum* are parasitic upon fish and other marine animals.

ORDER 2. *Acarina*, or *Monomerosomata* (*monos*, one, *meros*, a part, and *soma*, the body)—including the Mites and Ticks. The body consists of a roundish mass, exhibiting no trace of segmentation. They breathe by tracheæ. The family of the *Linguatulina* is remarkable in that, in their adult condition, the characters of the order are not easily traced, but the young, when still in the egg, are furnished with four pairs of jointed legs. The *Linguatulina* are found in the lungs of some of the mammalia. The family of the *Macrobiotidæ* are microscopic, and are known by the name of Sloth or Bear Animalcules. Their favourite habitat is under the gutters of houses. They resemble the Rotiferæ in so far as, though dried for a considerable time, they return to life the moment they are moistened. But the most familiar of all is the family of the *Acarida*, including the Cheese-mite, which has four pairs of legs, and uses them for walking. The *Sarcoptes scabiei* produces, by burrowing under the skin, the disease called 'itch.' The *Hydrachnidæ*, or water-mites, have their legs fringed, and swim about in water. The Ticks (*Ixodes*) have a 'rostrum,' which enables them to penetrate and attach themselves to the skin of their host, generally one of the beetles.

Acarus (Mite).

ORDER 3. *Adelarthrosomata*.—The abdomen is united to the cephalo-thorax, but it is always more or less distinctly segmented. The mouth is armed with jaws, and the tracheæ open by two or four openings on the under surface of the body. To this order belong the family of the *Phalangidæ*, or Harvest-spiders, characterised by the enormous length of their legs, which resemble stilts. The family of the *Cheliferidæ* includes the Book-scorpion, whose palpi are long, and terminated by long nippers like those of the scorpion. Their favourite habitat is amongst old books.

SUB-DIVISION (B). *Pulmonaria*.—These breathe by pulmonary sacs, which are involutions of the integument, opening on the surface of the body by stigmata, which lead into a blind chamber. They have six or more simple eyes. The *Pulmonaria* comprise two orders.

ORDER I. *Pedipalpi*—in which the abdomen is distinctly segmented, and attached to the cephalo-thorax. This order includes the family of the *Scorpionidæ* — which are amongst the largest and best known of the Arachnida. They have an elongated abdomen, armed at its extremity with a short curved claw. It is with this organ that the Scorpion inflicts its sting, which is doubtless very disagreeable, and often attended with troublesome symptoms, though its danger, to man at least, seems to have been overrated. The maxillary palpi are very large, and form prehensile organs like the claws of a lobster. With these they seize their prey, strike it with the sting, and then devour it. They have four pairs of stigmata opening on the under side of the abdomen. It is in the tropics that the Scorpions attain their largest development.

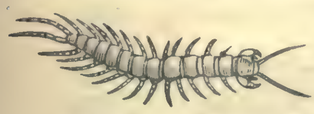
ORDER 2. *Dimerosomata* (Gr. *di*, two, *meros*, a part, and *soma*, a body) includes the true Spiders. The head and thorax are united into a single mass, and the abdomen is soft and unsegmented, being separated from the cephalo-thorax by a slight constriction. The head carries six or eight simple eyes. The mandibles are large, and perforated by the duct of a gland, which secretes a poisonous fluid. The palpi are never chelate or clawed. The pulmonary sacs are two or four in number, and open on the under surface of the abdomen. Tracheæ may also be present. But by far the most remarkable organs are the *spinnerets*, by means of which these animals spin their curious and beautiful webs for intercepting the prey upon which they expect to feed, or for lining their abodes. The spinnerets are teat-like organs, four or six in number; they are perforated at the apex by minute openings placed on the under surface of the abdomen. The substance composing the web is secreted by glands placed close to the spinnerets. It is viscid at first, and passes through the spinnerets, which give it its proper thread-like shape, becoming hard on exposure to the air. The *Argyroneta aquatica*, or Diving-spider, weaves for itself a bell-shaped cell, at the bottom of the water, to which it retires to devour its prey. It carries down air by entangling it amongst the hairs which cover its body. All spiders are predaceous, but some do not construct a web for the capture of their prey, such as the Tarantula (*Lycosa tarantula*) of Southern Europe, which springs suddenly upon its unwary victim. The *Mygale*, the most powerful of the spider order, when at rest, covers a space of six or seven inches in diameter. Other species are called Mining-spiders, because they construct their habitations in the ground, lining them with their silk-like secretion. The *Aranea domestica* (Common House-spider) is well known. The maxillary palpi of the male spider are specially constructed for bringing the male into contact

Spider, with thread-making organ magnified.

with the female element in the process of reproduction. Spiders are oviparous, but undergo no metamorphoses.

CLASS 3. *Myriapoda* have the head distinct, bearing a pair of antennæ, and usually a number of simple eyes. The thorax is united with the abdomen, the whole being divided into a large number of similar segments, each furnished with one or two legs on each side. They respire by tracheæ.

ORDER 1. *Chilopoda*, in which the number of joints composing the antennæ is never less than fourteen. *Lithobius forcipatus*, a British species, is about two inches in length, and quite harmless; but some of the *Scolopendra*, well known as Centipedes, found in hot climates, are powerful and predaceous, and sometimes measure one foot in length.



Lithobius forcipatus.

ORDER 2. *Chilognatha*, in which the antennæ are composed of only seven joints. It includes the vegetable-eating Millepedes (*Iulus*), characterised by the great number of the legs. The familiar Gally-worm (*Polydesmus*) is another example.

CLASS 4. *Insecta*—are articulate animals, in which the body is divided into three distinct regions—the *head*, *thorax*, and *abdomen*. The head carries the antennæ or feelers; the legs, six in number, being borne by the thorax; while the abdomen is destitute of jointed appendages. They breathe by tracheæ, and are generally furnished with wings attached to the thorax.

Considering the vast number and variety of insects that are found everywhere upon the earth, with their diversity of habits and structure, it must suffice here to point out the main characters of the class, merely mentioning some of the most important families. Indeed, the subject is so vast, that it is studied as a distinct branch of Zoology, under the term *Entomology*.

The body is never composed of more than twenty segments, which have usually a horny or chitinous investment, forming an exo-skeleton, to which the muscles are attached. The segments are united to each other by a membranous skin, thus giving flexibility to the whole. The segments of the head are united into a single piece, which bears the antennæ, the eyes, and organs of the mouth. The mouth is variously modified, according as it is suited for biting, for suction, or for both combined. In Masticating or Biting insects, such as Beetles, the mouth consists of six separate organs (see fig.). (1) An upper lip (labrum, *l1*) attached to the under surface of the head; (2) A pair of horny biting jaws (mandibles, *mm*); (3) A pair of chewing jaws (maxillæ, *mx*), bearing one or more pairs of 'maxillary palpi' (*mp*); and a lower lip (labium, *l2*) also bearing a pair of palpi (*lp*). The typical *suctorial mouth*, as seen in the Butterflies, consists of a long trunk, which, when at rest, is coiled up in a spiral form beneath the head. It represents the maxillæ, which, coming together, form a tube, through which the juices of the flowers are sucked up. The maxillary palpi are very small, and the labrum and mandibles are rudimentary. The labium, though very minute, bears two large palpi, forming the hairy cushions between which the trunk is coiled up when at rest. In the Bee, the parts are modified partly for biting, and partly for suction. The labium and maxillæ are elongated, the latter constituting a sheath which incloses the elongated tongue, thus forming a tubular organ, quite incapable of being coiled up, and through which fluid nutriment is sucked. The mandibles and labium retain their ordinary form. In Bugs and their allies, the labium forms an elongated tubular sheath, inclosing four bristle-shaped organs, which are the modified mandibles and maxillæ. The labium of the House-fly is lengthened and grooved on its upper surface. This groove receives the modified mandibles and maxillæ in the form of bristles and lancets, which are used for penetrating the skin and sucking the blood of other animals.

Mouth of a Beetle.

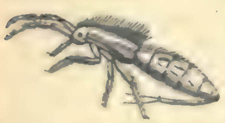
The thorax is composed of three segments, which are named from before backwards, *pro-thorax*, *meso-thorax*, and *meta-thorax*. Each of these bears a pair of jointed legs. The latter two segments also usually carry a pair of wings each. The legs are composed of several joints, named the coxa, trochanter, femur, and trasus. The wings are variously modified in the different orders, and consist of a double membrane, which is supported by hollow tubes or 'nervures,' which ramify in every direction, and contain processes of the tracheæ, and passages for the circulation. The abdomen is composed typically of nine segments, though these never carry legs. Some appendages connected with the generative function, or for leaping, for offence or defence, may, however, be connected with it. The *digestive system* in insects consists of a mouth leading into a gullet, which opens into a 'crop.' From this, in Masticating Insects, it leads into a 'gizzard,' furnished with horny plates. This gizzard leads into the true stomach, continued into the intestine, which terminates in a 'cloaca,' common to it and the generative organs. Salivary and other glands are present, but no absorbent system. The heart is placed dorsally, and consists of several sacs, which open into each other from behind forwards. The circulating fluid enters at the posterior extremity of the so-called 'dorsal-vessel,' and is propelled forwards by it, escaping anteriorly, and passing amongst the tissues, and, as it were, bathing them, for no true veins or arteries have been detected in the bodies of insects. In its course it is aërated by being exposed to the air contained in the tracheæ, which ramify throughout the body. The *nervous system* exhibits the typical annulose plan, and is placed ventrally. The eyes are usually compound—that is, they consist of multitudes of simple eyes, each of which receives a nervous twig. The eye of the house-fly has four thousand of these simple eyes. Insects are distinguished beyond all other animals by their powers of locomotion, and the perfection of their instinctive actions. The antennæ seem to be organs of touch. Insects are unisexual,

and most are oviparous. Many insects undergo changes of form (*metamorphosis*) in their development from the immature to the adult condition. Those which do not undergo this change are called *Ametabolic Insects* (Gr. *a*, without, *metabole*, change). The young of these insects resemble their parents in all respects except in size; moreover, they are destitute of wings. Those which only undergo a half-metamorphosis are called *Hemimetabolic Insects*. They undergo three stages. The young is termed *larva;* in the second stage it is *pupa;* and in the third, the perfect insect or *imago*. The larva differs from the imago in its smaller size, and in the absence of wings, while the pupa differs from it only in the wings being rudimentary. This metamorphosis is said to be *incomplete*. Those which undergo a *complete* metamorphosis are called *Holometabolic Insects*. The larva is worm-like, feeding voraciously, and growing rapidly. It is then called caterpillar or grub. After frequently changing its skin, it passes into the pupa or chrysalis state, when it becomes incased by a coriaceous covering, and seems all but devoid of life. Other larvæ spin for themselves a protective covering, which surrounds the chrysalis, and is termed the 'cocoon' (the *Silkworm*), while others reside in tubes constructed by themselves (the *Caddis-worm*). Finally, it emerges from this condition as the imago, or perfect insect, with fully developed wings, ready for flight.

SUB-CLASS I. *Ametabola*.—The young pass through no metamorphosis; imago destitute of wings; eyes, if present, are simple. It includes three orders.

ORDER 1. *Anoplura*—are typified by the Common Louse (*Pediculus*), a creature justly regarded with loathing, because it never exists unless in connection with dirty habits. The head bears two simple eyes and a suctorial mouth. They are all parasitic on mammiferous animals—man, the dog, and sheep having each an appropriate parasite of this order.

ORDER 2. *Mallophaga*—are specially common on birds, hence called *Bird-lice*. Their mouth is suited for biting, and they live on the more delicate portions of the feathers.



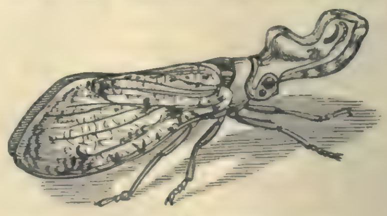
Podura villosa.

ORDER 3. *Thysanura*—includes the *Poduræ*, or Spring-tails, which possess a forked tail, curved under the animal, by suddenly extending which, they are enabled to spring to a considerable distance.

SUB-CLASS II. *Hemimetabola*—in which the metamorphosis is incomplete. This sub-class includes three orders.

ORDER 4. *Hemiptera* (*hemi*, half, *pteron*, wing). —Mouth suctorial, the labial palpi forming a sheath for the style-like maxillæ and mandibles, and thus protecting them. With these bristles, the insect pierces the plants or animals upon the juices of which it feeds. The head bears a pair of compound eyes, and usually also several simple eyes. Most of them possess four wings. This order is subdivided into

SUB-ORDER (A). *Homoptera* (*homos*, like, and *pteron*, a wing)—in which the anterior pair of wings are of similar consistence throughout, often somewhat parchmenty, and the mouth looks backwards, so that the rostrum springs from the back of the head. These are represented by the *Coccidæ* (Blight Insects)—for example, the *Coccus cacti* (Cochineal Insect), esteemed for the splendid colour it furnishes. It takes seventy thousand of these insects to make a pound of cochineal. An East Indian species (*Coccus lacca*) yields *shell-lac* and *lac-dye*. In these cases, it is only the female insect that yields the colouring matter. The *Aphides* (Plant-lice) inhabit trees or plants, to which they prove highly destructive, feeding, as they do, upon the juices they contain. They exhibit some very peculiar phenomena in their



Fulgora laternaria.

manner of reproduction. The *Fulgora laternaria* (Lantern-fly of Guiana), in which the forehead is much prolonged, is said to emit light in the dark. The *Aphrophora spumaria*, or Frog-hopper, a British species, also belongs to this group. Its larva envelops itself in a frothy secretion, which has received the name of 'cuckoo-spit.' The *Cicada* was celebrated by the Greek poets for its fine song, peculiar to the male, and produced by the vibration of a drum-like organ situated at the side of the abdomen.

SUB-ORDER (B). *Heteroptera*, or Bugs (*heteros*, different, *pteron*, a wing)—in which the wings are chitinous towards the base, and membranous towards the point, the beak springing from the front of the head. The Boat-flies or Water-bugs (*Notonecta*) haunt the surface of still waters. They use their hind oar-like feet for swimming, and with their anterior pair they seize their prey. The *Nepidæ* (Water-scorpions) are fierce insects, and lurk in ponds, living solely on insects. The *Cimicidæ* (Bugs) are unhappily familiar to us, by their intrusion into our bed-chambers. When irritated, they emit an offensive odour.

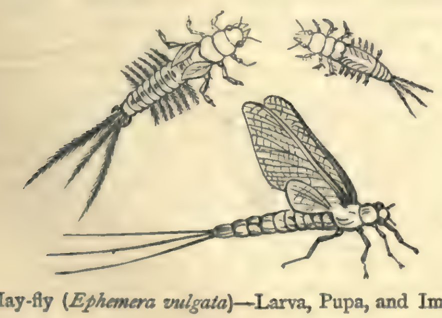
ORDER 5. *Orthoptera* (*orthos*, straight, *pteron*, a wing). The mouth is admirably suited for biting; wings four, the anterior pair of a leathery texture, and forming a protection for the posterior, which are larger, and folded in a fan-like form. This order contains two sections. The first of these sections, the *Saltatoria*, are all herbivorous insects, and have the hind-legs elongated, and fitted for leaping. It includes the family of the *Locustina* (Locusts), so common in warm climates. 'Wherever they alight, all signs of vegetation disappear, and cultivated grounds are left a desert.' The most common species is the *Locusta migratoria*, which is so formidable an enemy to agriculture in Southern Europe, and even reaches our own island. The *Gryllina* (Grasshoppers) have very long antennæ, and the largest British species is the *Gryllus viridissimus*, measuring about two inches in length. They are so pugnacious that if two are put into a box, they almost invariably fight, and the victor dines off the legs of the vanquished. The other British species are all of

small size. These are the little chirpers which we hear on heaths and sunny banks. The *Achetidæ*

Female Grasshopper (*Gryllus viridissimus*).

(Cricket family) are a very noisy race; for the chirping of the House-cricket (*Acheta domestica*), produced by the rubbing of the elytra-cases against each other, can be heard at a considerable distance. The Field-cricket (*A. campestris*) and Mole-cricket (*Gryllotalpa vulgaris*) also belong to this family. The section *Cursoria* have the legs long, and suited for running. The *Mantina* have the fore-legs converted into powerful raptorial organs. They are carnivorous, and very pugnacious. The Chinese amuse themselves with their combats, keeping them for this purpose in cages. The *Blattina* (Cockroaches) are nocturnal insects, which infest kitchens and bakehouses. The Common Cockroach (*Blatta orientalis*) is too well known to require description. The *Forficulidæ* (Ear-wigs) are likewise placed in this section.

ORDER 6. *Neuroptera* (Nerve-wing)—have four membranous wings, which are reticulated or interlaced with a delicate network of fine nervures. Metamorphosis in some is complete, though in most it is incomplete. The *Libellulidæ* (Dragonflies) are slender in form, and beautiful and varied in their colouring, though very voracious in their habits. They have four large, nearly equal reticulated wings, and a powerful masticatory apparatus. Their larvæ and pupæ inhabit the water. The *Ephemeridæ* (May-flies), also called Day-flies, from the short duration of their life in the perfect state, are found, during autumn and summer, in every



May-fly (*Ephemera vulgata*)—Larva, Pupa, and Imago.

brook and pond. The *Termitidæ* (White Ants) are social insects, living in vast communities, and chiefly confined to warm climates. They construct most beautiful habitations either on the ground or on trees, and assist in the removal of dead and decomposing organic matter. The *Myrmeleontidæ* or Ant-lions, whose larvæ are so destructive to ants, live, in the perfect state, upon the nectar of flowers. The larvæ entrap their prey by excavating conical pits in sandy places, at the bottom of which they conceal themselves entirely, with the exception of the head and powerful jaws. When an unfortunate ant or other insect falls into this pit-fall, it is soon devoured by the voracious myrmelio.

SUB-CLASS III. *Metabola*—in which the metamorphosis is 'complete.' It includes six orders.

ORDER 7. *Aphaniptera*—includes the Common Flea (*Pulex irritans*). The wings are rudimentary, and represented by four scales. The mouth is suctorial, and its power to penetrate the human skin, for gastronomic purposes, is too well known.

ORDER 8. *Diptera*—have only a single pair of wings developed—namely, the anterior; the posterior pair being rudimentary, and represented by organs called 'halteres' or 'balancers.' The mouth is suctorial. The *Hippoboscidæ* (Horse-flies or Forest-flies) are parasitic upon other animals. *Hippobosca equina* infests the horse, and *Melophagus ovinus* is the Sheep-tick. Amongst the *Muscidæ*, or Flies, the most familiar species is the *Musca domestica* (House-fly), whose larvæ are bred in manure, and undergo their change in a few days. Their purpose is to consume substances which would taint the atmosphere. They possess the power of flying backward. The *Tabanidæ* or Gad-flies have a suctorial mouth, provided with six lancets, with which they pierce the skin of their victim. The Cleg (*Tabanus pluvialis*) is familiar to most of us. Many of the *Tipulidæ* (Water-spinners), in their larval condition, are very destructive to the roots of grass and to wheat-crops. The *Culicidæ*

Gnat, magnified:

1, insect depositing eggs; 2, insect escaping from pupa case; 3, larva of gnat; 4, floating raft of eggs.

(Gnats) are specially blood-thirsty, and the disagreeable effects of their bite are frequently enough experienced. Their larvæ are aquatic. The Mosquitoes of warm climates interfere so much with our ease and comfort as to become one of the worst of pests. The Midge, so well known for its aerial dances, is the smallest species of the family.

ORDER 9. *Lepidoptera* (Gr. scaly-winged), Moths and Butterflies.—The structure of the mouth has been described already. The wings, four in number, are covered by minute scales, which are implanted on the membrane of the wing like the tiles on a roof. The beautiful metallic colouring which occurs in many species of this order is not due to the presence of pigment, but is owing to these minute scales having

upon them numerous delicate striæ, which break up the rays of light, and so cause the iridescent appearance. The *Lepidoptera* feed upon fluid nutriment. The larvæ are known as Caterpillars, which have a masticatory mouth; and when they attain their full size, they spin around their bodies a case or cocoon of silk, in which to spend their life as a pupa or chrysalis. From one species we derive the silk which is woven into one of the most elegant kinds of cloth. The glutinous matter of which the threads are composed is secreted by glands analogous to the salivary glands. It is forced through a small opening at the end of the lip, and hardens as it is exposed to the air. Some species, however, form no cocoon,

Argynnis Paphia.

but hang in the pupa state from some lofty place. At the proper time, the perfect insect bursts from its case, to spend a brief, gay existence in the air, to lay its eggs, and then perish.

Family *Papilionidæ* (Butterflies) are also called *Diurna*, because they fly about during the day, and are distinguished by the extraordinary beauty and variety of the colours which adorn their wings. Their antennæ are almost always terminated by a knob. Over 2000 species exist in Great Britain alone; but it is in tropical climates where these most beautiful of all insects attain their greatest size, and exhibit the greatest variety of absolutely dazzling hues.

Family *Sphingidæ* (Hawk Moths), or *Crepuscularia*, so called from their general habit of flying abroad at twilight. Their colour is duller than the butterflies, and when flying, they make a humming noise. The Death's-head Moth (*Acherontia atropos*) has a skull-shaped patch of colour on the back of the thorax, and its sudden appearrance has been regarded as an evil omen.

Family *Noctuina*, or Moths Proper, fly only by night, and are of a dull style of colouring. This family includes the Silkworm (*Bombyx mori*), a native of China. It was imported into Europe in the reign of the Emperor Justinian, in 550 A.D. The caterpillar of the silkworm, when it has attained its full size—three inches long—and before it passes into the chrysalis stage, spins for itself an oval ball or cocoon composed of a long slender filament of yellow silk. After emancipating itself from its silken prison, it seeks its mate. In two to three days afterwards, the female having deposited her eggs, from 300 to 400 in number, both insects terminate their existence.

ORDER 10. *Hymenoptera* (or Membrane-winged)—in which the wings are four in number, of a membranous texture, with few nervures, the anterior being larger than the posterior pair; they are sometimes absent. Mandibles are always present, and the arrangement of maxillæ and labium into a suctorial organ has been described already. The females are furnished at the extremity of the abdomen with an ovipositor, and in some species (Bees, Wasps) this organ is modified, so as to constitute a most formidable offensive weapon. Many possess instinct of a very high degree, and some live in social communities, as the Bees and Ants. This order includes the following families:

Tenthredinidæ (Saw-flies). The females have an ovipositor which combines the properties of a saw and a file. With this, they bore a series of holes in trees, depositing in each an egg, with a drop of frothy liquid, which seals up the hole. The larvæ have from ten to sixteen feet, and so are easily distinguished from the caterpillars of the *Lepidoptera*, which they resemble.

Ichneumonidæ (Ichneumons). These are parasitic, and insert their sting into and deposit their eggs in the larvæ of other insects, where the young, when hatched, find sufficient nourishment. The grub ultimately falls a victim to its ravages; though they carefully avoid injuring the vital parts of the larva on which they prey. Scarcely an insect exists which in the larval stage is exempt from attacks from one or other species of this family, so numerous are they.

Cynipsidæ (Gall-flies). These insects deposit their ova in living trees, and by their presence give rise to the formation of excrescences, called *galls*, such as those on the leaves of the oak-tree. The larvæ feed on the interior of their habitations, where they remain for five or six months. Some undergo their metamorphoses within the galls, but others escape through small apertures to undergo that change. Galls are imported from the Levant, and are used in the manufacture of writing-ink and dye-stuffs.

Formicidæ (Ants), so celebrated for their industry, live in societies, often of great extent, consisting of three distinct kinds of individuals—males, females, and neuters. The males are winged during the whole of their existence, the females during only part of their mature state. At a certain period in summer, the males and females appear in large quantities, quit the nest, and copulate in the air, when the males speedily die. The females then lose their wings, fall to the ground, and are picked up and carried to the nest by the neuters, when they become the queens of future societies. The neuters form the great bulk of the community, and upon them depends the entire labour of the community. They are really females in which the sexual organs are undeveloped from the difference of food in the larval stage. They construct the nest, and attend upon and feed the young larvæ. Like the females, they possess a sting. The larvæ of ants, unlike those of bees, are never inclosed in cells. The food of most species of ants consists chiefly of aphides or plant-lice. Some species in India and in the south of Europe hoard grain and other seeds. The nests of ants consist of numerous chambers communicating by winding and tortuous passages, and they are sometimes excavated in the ground, at other times in the trunks

Neuter Ant (Worker).

of old trees. Some ants, as *Formica rufescens*, have the very peculiar instinct of capturing the pupæ of other ants and making slaves of them. Ants have another very strange habit—namely, that of *milking* the aphides or plant-lice. These aphides excrete a saccharine substance, or honey-dew, of which the ants are extremely fond. To obtain this, the ant pats the abdomen of the aphis with its antennæ, and when the drop has been obtained, it passes on to another aphis.

Vespidæ (Wasps) generally form large communities, composed of males, females, and neuters. A colony is commenced in spring by young females which have lain dormant during the winter, when they set about building a nest, in which they lay eggs, and attend to the larvæ. The first brood consists of workers, upon whom ultimately depends the work of the community. The nest is made of a paper-like pulp, made by masticating and moistening the wood or bark of a tree.

Of the *Apidæ*, or Bees, some are solitary, while others live in detached communities, under the apparent rule of an individual. Amongst *Social Bees*, such as the *Humble* and *Hive Bees*, only one in each hive is a true female, distinguished by her size, and called the *queen*. About six hundred are males, usually called *drones*, and the remainder, about fifteen thousand, are *neuters*, destined for labour. The queen, in the larval state, is furnished with a cell of royal dimensions, and is supplied with the most nutritious and delicate kind of food. In due time, she comes forth in all the dignity of majestic size and full colouring. The neuters are placed in six-sided cells, so proportioned as to limit their growth, and prevent their full development. They are fed on simple fare. The males exist only between April and August, when they are destroyed by the workers. The cells are six-sided, and are so constructed as to yield at the same time the least expenditure of material with the greatest strength ; the instinct of an insect thus coming to the very same result as the highest human intelligence. In some cells, honey is stored up, and in others the eggs are laid. The eggs from which perfect females or queens are to be produced are laid in cells much larger than the rest, and of different forms. The drones are killed at the end of summer, but the queen and the workers remain ; and when the hive is over-peopled, colonies are sent forth with young queens in search of another habitation.

The *Solitary Bees* present great variety of habit, some, such as the Carpenter Bees (*Xylocopa*), making their nests in old wood ; the Mason Bees (*Osmia*) construct their nests by gluing together grains of sand ; while the Cuckoo Bees (*Nomadæ*) build no nest at all, but deposit their eggs in the nest of other species.

ORDER 11. *Strepsiptera*—are parasitic in the interior of Bees and Wasps. The females have no wings, but the males have a pair—the posterior—of large membranous wings, folded longitudinally. Neither the jaws nor the anterior pair of wings are developed.

ORDER 12. The *Coleoptera* (*koleo*, a sheath, and *pteron*, a wing), or Beetles, have the anterior pair of wings horny or chitinous, and forming a protective covering (elytra) for the posterior pair. The mouth is masticatory, and possesses both mandibles and maxillæ. The metamorphosis is complete, and the pupa is inactive. They are the most numerous and best known of all the orders of insects.

The primary division of Beetles is founded upon the number of joints in the divisions of their feet or *tarsi*.

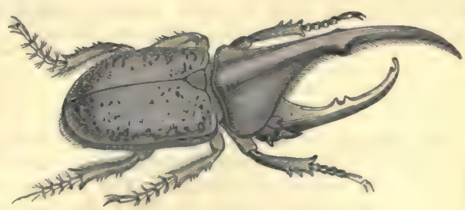
Section Trimera, or beetles which have only three joints in their tarsi. The Two-spotted Lady-bird (*Coccinella bi-punctata*), so called from having two spots on its elytra, is an example. Its larvæ feed upon aphides, so that these insects ought to be encouraged, and they are of great use to land-owners by devouring the aphides which swarm on hops.

Section Tetramera contains such beetles as have four joints in each foot. They all feed upon vegetable substances. It includes the Weevils (*Curculionidæ*), which have the anterior part of the head extended into a kind of muzzle. They are dangerous enemies to our vegetable stores. The *Xylophagi*, or Wood-eaters, are small in size, but exceedingly numerous, and do almost incredible mischief to mankind. The *Longicornes*, distinguished by the length of their antennæ, in their larval state bore deep tunnels into trees.

Section Heteromera, which have five articulations in the first four tarsi, and only four in the hindmost pair. They are terrestrial in their habits, live chiefly in dark places, and feed upon vegetable substances. The Churchyard Beetle (*Blaps mortisaga*), found in dark and dirty places about houses, is a well-known example. The larva of *Tenebrio molitor* is known as the Meal-worm. The *Trachelidæ* have the head supported on a pedicle or neck. Example—*Lytta vesicatoria* (Blister-fly) is very common in Spain, and hence the common name, Spanish-fly. The beetles are shaken from the trees, and collected in sheets spread upon the ground, and are killed by exposure to the fumes of vinegar.

Section Pentamera.—The majority of insects in this section have five joints in the tarsi. It includes several families—for example :

The vast family of the *Lamellicornes* have the antennæ club-shaped, composed of thin plates arranged like the leaves of a book, which they can open or shut at pleasure. They are entirely vegetable feeders, and vary much in form, colour, and size. The *Cetonia aurata* (Rose-beetle) may be taken as the type. It includes also the sacred Egyptian Beetle (*Ateuchus sacer*), which was consecrated to the sun, and therefore regarded as an emblem of fertility ; the Stag-beetle (*Lucanus cervus*) ; and the Cockchafer (*Melolantha vulgaris*). The *Dynastes Hercules*, a native of Brazil,



Dynastes Hercules.

sometimes attains a length of five inches. It has a horn projecting from the head, which is opposed by a corresponding protuberance from the thorax.

The family of *Palpicornes* have the antennæ long, club-shaped, and leaf-like. Their feet are suited for swimming. The genus *Hydrophilus* is common in Britain, being found in ponds and ditches.

The family *Clavicornes* have the antennæ thick, and terminated by a solid mass. In their habits, they are partly aquatic and partly terrestrial. The *Necrophorus*, or Burying-beetle, is a remarkable genus, so called from burying small quadrupeds, such as mice and moles. They deposit their eggs in the carcass, upon which the young feed during their larval stage.

The *Serricornes* have the antennæ serrated or saw-shaped, and the elytra completely covering the body. The Wire-worm, which devours the roots of corn, often to a disastrous extent, is the larva of *Elator obscurus.* The genus *Lampyris*, or Glow-worm, is remarkable for the light it emits at night. The females especially possess this property. The body is soft, and the light resides in the last two or three sections of the abdomen. The 'Death-watch' (*Anobium*) makes a ticking noise with its jaws while perforating wood; and as this is usual in a sick-chamber, and is consequently apt to be heard before one dies, the noise so made is held by the ignorant mind to be a warning of death, hence its common name.


Firefly (*Lampyris Italica*).

The *Brachelytra* are so called from having short crustaceous wing-coverings, and are represented by the single genus *Staphylinus*, which is frequently seen running about garden walks.

The *Dytiscidæ* are aquatic in their habits. Their feet are fringed with broad stiff hairs. They have to come to the surface of the water to breathe, as their respiratory organs are the same as other insects.

Carnivora.—These beetles have been placed by entomologists at the head of this order, on account of the structure and development of the organs which fit them for a mode of life pre-eminently carnivorous. The mandibles are armed with strong and powerful teeth. They are remarkable for the beauty of their colours, and hence the name of Tiger-beetles. They prey, even in their larval state, upon other insects. The Common Beetle (*Cicindela campestris*) is about half an inch in length, of a green colour, with whitish spots on the elytra, and may be seen running about in sandy fields, exposed to the hottest sunshine.

V. SUB-KINGDOM MOLLUSCA.

The *Mollusca* (Lat. *mollis*, soft) are soft-bodied animals, exhibiting bilateral symmetry, usually protected by an outer skeleton. The alimentary canal is completely shut off from the general body-cavity. A nervous system is always present, and consists of a single ganglion, or of scattered pairs of ganglia.

The *Mollusca* may be divided into two chief divisions:

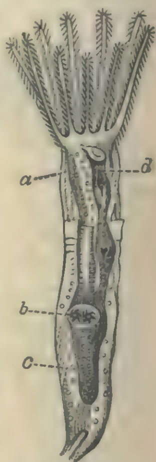
I. *Molluscoida*, in which the nervous system consists of a single ganglion, or of a principal pair with accessory ganglia. Heart very imperfect, consisting of a simple open tube, or entirely absent.

II. *Mollusca* (Proper), in which the nervous system consists of three principal pairs of ganglia. Heart always well developed, and consisting of at least two chambers.

I. The *Molluscoida* include the following three classes:

CLASS I.—POLYZOA.

The *Polyzoa* or *Bryozoa.*—'Animals always forming composite colonies, each zoöid of which consists of an alimentary canal suspended in a double-walled sac, from which it can be partly protruded by a process of evagination, and into which it may again be retracted by invagination. The mouth is surrounded by a circle of hollow ciliated tentacles.' *Plumatella repens*, a fresh-water species, may be taken as the type. It is a composite animal; each individual consists of a sac with a double wall. Within this is suspended the alimentary canal. The hollow ciliated tentacles surrounding the mouth are concerned partly in respiration, and partly in creating currents in the water, and so bringing food to the animal. The intestine can be protruded from, or retracted within the sac by means of muscles. The intestine is curved, so that the anus opens near the mouth. No heart or blood-vessels are present. The fluid within the perivisceral cavity, which is supposed to represent the blood, is clear and colourless, and is kept in continual motion by the cilia lining the inner surface of the body-wall. The nervous system consists of a single ganglion, placed between the gullet and the anus. They (*Bryozoa*) are all hermaphrodite, and reproduction takes place by budding and by eggs.



Bowerbankia: *a*, œsophagus; *b*, gizzard; *c*, stomach; *d*, orifice of intestine.

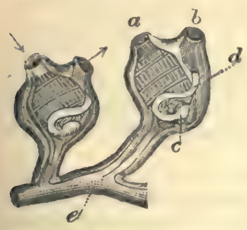
The Sea-mat (*Flustra*), so common on our shores, is a well-known example. It is flat and leaf-like in its form, and on the whole it presents an appearance like brown sea-weed, for which it is often mistaken. But, on examining its surface carefully, it is seen to be studded over with little openings, through which the little animals can protrude their tentacles.

CLASS II.—TUNICATA OR ASCIDOIDA.

The *Tunicata* are defined as having the 'alimentary canal suspended in a double-walled sac, but not capable of protrusion and retraction. Mouth opening into the base of a respiratory sac, whose walls are more or less completely lined by a network of blood-vessels.'

They are all marine. Take one of the solitary forms, *Ascidia*, as the type. It is globular in form, and consists of a double-walled sac, the outer layer of which contains cellulose, and is of a tough leathery consistence. It is perforated by two apertures placed close to each other, one the oral, the other the anal opening, so that the whole

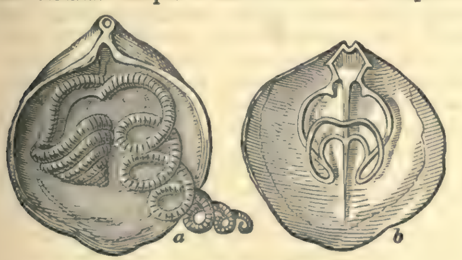
animal resembles a double-necked bottle, hence the name of Ascidian (*ascus*, a bag). The inner bag is perforated like the outer. The mouth leads into the large *respiratory* or *pharyngeal sac*, which is continued at its lower end into the œsophagus. This respiratory sac is perforated by a number of apertures, and is richly supplied with blood-vessels, for it is here that the blood is aerated. The intestine is twisted on itself, and does not open on the surface directly, but through the medium of a cloacal chamber. The circulatory apparatus differs remarkably from that of all other animals. It consists of a simple open tube without valves, which pulsates rhythmically. The blood is driven first through one end, and then through the other, so that the course of the blood is periodically reversed. The nervous system consists of a single ganglion placed on one side of the mouth. The Ascidians are all hermaphrodite. Some forms are composite, as *Botryllus*, which is also fixed. Others, such as *Salpa*, are free, and float on the surface of the sea, their tunic being so delicate and transparent that they would scarcely be observed if it were not for their iridescent appearance. The *Tunicata* have attracted a considerable amount of attention lately, from the fact that, while in their embryo state, their nervous system presents appearances somewhat resembling those found in the little fish the Lancelet or *Amphioxus*, the lowest of vertebrated animals.



Section of Social Ascidian: *a*, mouth; *b*, vent; *c*, stomach; *d*, intestinal canal; *e*, common tubular stem.

CLASS III.—BRACHIOPODA.

The *Brachiopoda* (arm-footed), are so called because of their possessing two long ciliated arms, supposed to be for creating currents, thus bringing food to the mouth, which is placed at the bases of the arms. The animal is inclosed in a bivalve shell, lined by a mantle. The two valves of the shell are united by a hinge, and kept in position by means of muscles. The valves are generally of unequal size, the larger one being in some cases provided with a beak, which is perforated by an aperture, and hence the common name of *Lamp-shells*, from their supposed resemblance to the old Roman lamps. The valves with respect to the body are placed ventrally and dorsally. The *Brachiopoda* are all marine, and all the known living forms are fixed. The shell is lined by, and is a secretion from the mantle, a strong muscular tunic which invests the soft parts of the animal. The long arms are in some genera supported by a calcareous framework called a *carriage-spring apparatus*. The arms probably perform the function of respiration, and the nervous system consists of a single ganglion, placed between the mouth and the anus. It includes the genera *Lingula*, *Terebratula*, *Crania*, &c. The *Brachiopoda* were very abundant in some rocks, particularly in the Silurian formations, where they appear to have attained their maximum of development. The genus *Lingula* is found in the lowest fossiliferous rocks, and what is very remarkable, this genus still exists at the present day.

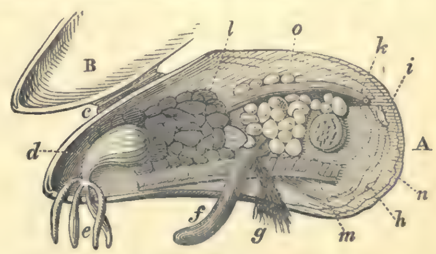


Terebratula:
a, valve with the spiral arms; *b*, valve with arms removed.

II. The *Mollusca* proper, which include the following four classes:

CLASS IV.—LAMELLIBRANCHIATA.

The *Lamellibranchiata* (plate-shaped gills)—including the so-called 'Shell-fish,' as Oysters, Mussels, Cockles, &c. They have no head, are inclosed in a bivalve shell, and have two lamelliform or plate-like gills on each side of the body, and neatly arranged within the margin of the shell. The body is inclosed in a mantle, from which the shell is secreted. The mantle is more or less completely attached to the shell. This is indicated in the interior of the shell by a line called the *pallial line*. In some bivalves, the edges of the mantle are united, so that a closed respiratory chamber is the result, to which water is admitted by means of a 'siphon,' which is just the mantle lobes united and perforated by two tubes, through one of which the water enters, and is expelled through the other. This siphon can in most cases be retracted within the shell. In the shell of those bivalves which do not possess a siphon, the pallial line is simple, and is not indented; but in those which have a siphon, the pallial line forms a deflection inwards, like a little bay, to which the muscles that retract the siphon are attached. The valves of the shell, unlike those in the *Brachiopoda*, are equal and alike, and, with respect to the body of the animal, are placed laterally, that is, right and left. Further, the valves are closed by muscles called *adductors*, but are opened by an elastic ligament, and a cushion of cartilage, which is placed between the beaks of the valves, so that, when the creature approximates the valves, the elastic ligaments, being placed behind the beaks of the valves, are put on the strain, while the cartilage is compressed, so



Interior of Mussel:
A, right valve; B, left valve; *c*, hinge; *d*, stomach; *e*, tentacula; *f*, foot; *g*, byssus; *h*, branchial orifice; *i*, vent; *k*, termination of intestine; *l*, liver; *m*, gills; *n*, adductor muscle; *o*, ovarium.

that, when the animal wants to separate the valves, it has only to relax the muscles, and the shells fly apart, in virtue of the elasticity of the elastic ligaments and the cartilage. In the Brachiopoda, the valves are both closed and opened by means of muscular action. The heart is always well developed, and consists of at least two chambers, and the blood is aerated in the plate-like ciliated gills. The nervous system consists of three well-defined ganglia. In many of the *Lamellibranchiata*, there is present a muscular organ called the *foot*, which is used in progression. This class comprises two sections, namely:

Section (A). *Asiphonida*—in which no respiratory siphon is present, the pallial line is not indented, and the lobes of the mantle are free, and not united. This section includes the Oyster family (*Ostreadæ*), represented by the *Ostrea edulis*, the Common Edible Oyster, which is deficient in a foot, and is fixed to the sea-bottom by the shell alone. It has its headquarters in Britain, and is considered full-grown for the market in from four to seven years. The Common Pecten, the type of another family, is so called from the resemblance of its shell to a comb, has a well-developed foot, and a number of brightly coloured spots placed along the edge of the mantle, which are supposed to represent eyes.

The *Mytilidæ*, represented by the Common Mussel (*Mytilus edulis*), so abundant on our shores, has a quantity of hair-like filaments (*byssus*) developed in connection with the foot, by which it attaches itself to solid objects. Of the family *Unionidæ*, the *Unio*, or Fresh-water Mussel, is noted for producing small pearls. They all inhabit fresh water, and the shell is covered by a very thick epidermis. The *Unio pictorum* is so called from its shell having been used by painters to hold colours.

Section (B). The *Siphonida*—possess a siphon, and the mantle lobes are more or less united. In some, the siphons are short, and the pallial line simple, as in the Cockle family (*Cardiadæ*), in which the foot is well developed, and fitted for burrowing in the sand of the sea-shore. The Common Cockle (*Cardini edule*), which is eaten in some localities, can spring to a considerable height by means of its bent foot. In others, the siphons are long, and the pallial line is indented, as in the Myas, which burrow and form a habitat for themselves. The Solen, or Razor-shell, sinks in the sand with great rapidity. The Pholas has a shell composed of arragonite, and can perforate timber and solid rocks, thus producing great destruction by attacking ships and wooden piles in water. Another celebrated species is the *Teredo navalis*, or ship-worm, a worm-like animal, furnished with two small shells at its anterior extremity, often attaining the length of one or two feet, and doing immense damage by boring into timber.

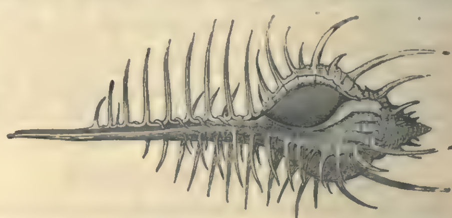
CLASS V.—GASTEROPODA.

Animals with the head well developed, and never inclosed in a bivalve shell. Locomotion effected by a horizontally flattened ventral disc ('foot'), or by a vertically flattened ventral fin-like organ. This class includes the *univalved* shells, such as the Snail and Whelk. In the mouth, there is a peculiar strap-shaped masticatory apparatus called an *odontophore*. The mantle is continuous round the body. The heart consists of an auricle and a ventricle. In one group, respiration is effected by an apparatus for breathing the air in water (*Branchifera*); in the other, the respiration is aerial (*Pulmonifera*). The sexes are mostly distinct. The young *always* possess an embryonic shell. The shell is composed either of a single piece (*univalve*), or of many pieces (*multivalve*). This class comprises:

Section (A). *Branchifera*—in which the respiration is aquatic. This section includes three orders, characterised according to the position of the branchiæ.

ORDER I. The *Prosobranchiata* have the mantle so arranged as to form a vaulted chamber over the back of the head, in which the respiratory organs, or branchiæ, are usually lodged. These gills are situated in front of (*proson*) the heart. This order is divided into two sections:

1. The *Siphonostomata*, in which the aperture of the shell is notched or produced into a canal. They are all marine, and carnivorous in their habits—for example, the Whelk family (*Buccinidæ*), represented by the Common Whelk (*Buccinum undatum*), in which the shell is of a spiral form. The *Volutidæ* contain many beautifully marked shells, and are chiefly confined to warm latitudes. The Cowry family (*Cypræidæ*), so remarkable for their beauty, are largely used as mantel-piece ornaments. In certain parts of Africa, the shell of *Cypræa moneta*, or Money Cowry, is used by the natives as money. The *Muricidæ* (*murex*, purple)

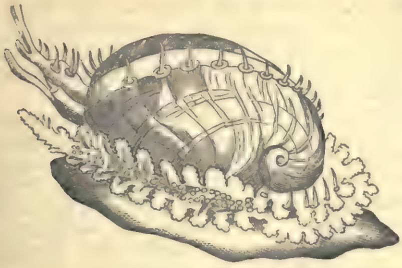


Murex tenuispina.

have a univalve spiral shell, with a small oval aperture ending in a straight ascending canal. The *Strombidæ*, or Wing-shells, have the aperture of the shell much dilated, and the lips expanding and extended into a groove leaning to the left.

2. The *Holostomata* have the aperture of the shell entire. They are chiefly plant-eaters, and are either marine or inhabitants of fresh water. It includes a great many families—for example, the *Patellidæ*, or Limpet family. In the Common Limpet (*Patella vulgaris*), locomotion is at a low ebb, for they seldom move far from the place where they are produced. The *Haliotidæ* (Ear-shells) are used in making those mother-of-pearl ornaments which constitute so much of the beauty of works in papier-mâché. The Marine Snail family (*Turbinidæ*) have the shell of a regular turbinated form. They are found in great abundance in the Indian seas, and are used as food, many being of large size. The Common Periwinkle (*Littorina littorea*) is nearly allied to this family. In the *Dentalidæ*, the shell is tubular, slightly curved, open at both ends, and shaped like an elephant's tusk, hence their name of Tooth-shells. The Chiton family (*Chitonidæ*) have multivalve shells, the mantle being covered by

eight testaceous symmetrical plates placed transversely. These animals live on rocks and stones



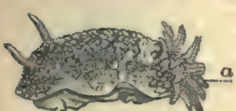
Haliotis tuberculata.

on the sea-coast, and are distributed nearly over the whole globe.

ORDER 2. In the *Ophisthobranchiata* (Gr. *ophisthen*, behind, and *bragchi*, a gill), the shell is rudimentary, and the branchiæ are more or less completely exposed on the back and sides towards the posterior extremity of the body. They are commonly called 'Sea-slugs,' and are divided into two sections:

Section (*a*). *Tectibranchiata* comprehends those species in which the gills are protected by the shell or mantle. They are all marine, living chiefly on the shore or on floating sea-weed. In the family of the *Bullidæ* (Bubble-shells), the shell is large and convolute, and in some cases is large enough to receive the greater part of the animal. The *Aplysiadæ* are slug-like in form, and have the mantle very large, and reflected upwards, so as to cover in the gills. They possess a merely rudimentary shell, and owing to their tentacles being turned backwards, like ears, they are popularly known as 'Sea-hares.'

Section (*b*). *Nudibranchiata*, in which the shell is absent, and the branchiæ are exposed on some part of the back in the form of a rosette. It includes all the naked marine Gasteropods, as *Doris* (Sea-lemon), *Triton*, and *Tethys*. They are elegant and beautiful little creatures, like slugs, and are generally ornamented with beautiful colours. They are found creeping on sea-weeds or attached to stones at low-water.



Doris: *a*, gills.

ORDER 3. The *Heteropoda* have the foot compressed into a thin vertically flattened ventral fin, by means of which locomotion is effected. They are free-swimming and pelagic. This order comprises two families, *Firolidæ* and *Atlantidæ*. In the *Firolidæ*, the shell is absent, or exists in a rudimentary form, and protects the circulatory and respiratory organs, including the genera *Carinaria* and *Firola*. In the *Atlantidæ*, such as Atlanta and Bellerophon, the shell is large, and capable of containing the whole animal.

Section (B). The *Pulmonifera* are characterised by having their respiratory organs so arranged as to breathe air directly. The mantle is inflected so as to form a pulmonary chamber, into which air is admitted from without, and where it comes in contact with the plenus of vessels with which the wall of the chamber is supplied. They are hermaphrodite. Most of them are land animals: although a few are aquatic, living chiefly in fresh waters and brackish pools, they are forced to come to the surface to breathe. This section includes two orders.

ORDER 4. *Inoperculata.*—The animals in this order are not provided with an operculum for closing the shell. The family of the *Helicidæ* (Land-snails) are among the most familiarly known of all animals. The shell is large, and capable of containing the entire animal. They feed exclusively on vegetables, and the destructiveness of the Garden-snail (*Helix hortensis*) is well known. In tropical climates, the genus *Bulimus* sometimes attains to a great size. The tropical *Achatina* is distinguished by the beautiful colours of its shell. The family of the *Limacidæ* (Slugs) are naked snails, and are very destructive to vegetables. The head bears

Mature Snail.

four tentacula, and at the end of the longer pair the eyes are situated. These tentacula (usually called the 'horns') can be drawn in by a process resembling the inversion of the finger of a glove. The family of the *Lymnæidæ* (Pool-snails) reside in stagnant waters, feeding upon plants and seeds. The shell is thin, well developed, with the aperture simple, and the lip sharp. The *Lymnæa* is connected with the development of the immature cercaria into distoma. In the genus *Planorbis* (Marsh-snails), the coils of the shell are all upon the same plane.

ORDER 5.—In the *Operculata*, the shell is provided with an *operculum*, which is a horny or calcareous disc attached to the foot, and is drawn into the mouth of the shell by the contraction of the animal. It includes the genus *Cyclostoma*, a snail-like animal provided with a thin spiral shell, with the margins usually reflexed all round.

CLASS VI.—PTEROPODA.

The *Pteropoda* (wing-footed) are free-swimming oceanic forms, provided with two wing-like appendages on each side of the anterior extremity of the body. They are small animals, and exist in all seas, but are found in enormous multitudes in the Arctic and Antarctic Oceans. One of them, the *Clio Borealis*, forms the chief food of the whale, which swallows thousands at a mouthful. They are eminently carnivorous, feeding upon minute crustaceans and other small animals.

Example of the Pteropoda (*Cleodora pyramidata*).

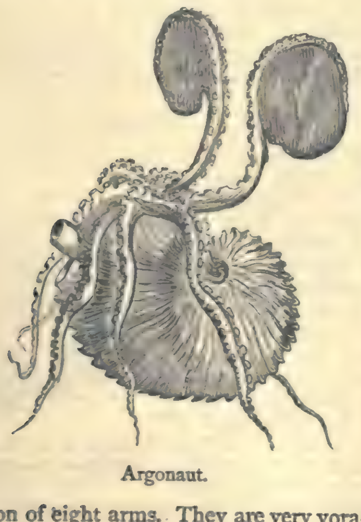
CLASS VII.—CEPHALOPODA.

The *Cephalopoda* are so named from having their limbs arranged in immediate connection with their head. These limbs are eight or ten in number, and perform all the functions of feet, arms, and feelers. The body is inclosed within a muscular mantle-sac. Through the anterior tubular orifice ('funnel'), the effete matter of respiration is expelled. They are the most highly organised of invertebrate animals, presenting rudiments of an internal skeleton. The eyes are well developed, and, in most of the existing species, organs of hearing are present. The head is large and conspicuous. They possess distinct hearts for the systemic and pulmonary circulations, and highly complicated nervous, digestive, secretory, and respiratory organs, which are in the form of two or four plume-like gills, situated within the mantle. They are all marine and carnivorous.

ORDER 1.—The *Dibranchiata* are specially suited for swimming rapidly through the water. These animals have two gills and three distinct hearts; an ink-sac for secreting and emitting an inky fluid; and the arms never above ten in number, and supporting suckers. The funnel is a complete tube, and the shell is internal, or, if external, it is not chambered. The Cuttle-fish are the most typical members of this order. They swim backwards by means of the jet of water expelled through the funnel, and by means of their arms and suckers they creep on the bottom of the sea, and retain a forcible hold of their prey. This order is divided into two sections, characterised by the number of their arms.

Cuttle-fish.

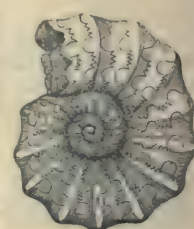
Section 1. *Octopodidæa* are distinguished by the possession of eight arms. They are very voracious animals, and to this family belongs the Poulpe (*Octopus*) of the Mediterranean, whose shell is placed internally. It is eaten as a regular article of diet in the south of Europe. In the Paper Nautilus (*Argonauta*), the female alone is protected by a very delicate and beautiful external non-chambered shell. The male argonaut is only about one inch in length.



Argonaut.

Section 2. The *Decapoda* have ten arms, two of which are longer than the others (tentacles), of a rounded form, and club-shaped at the extremity. The suckers are placed on stalks, and the body has a fin-like organ on each side; further, the shell is always internal. It includes the *Calamaria*, or Squids—for example, *Loligo*, the shell of which is horny, and is called the 'cuttle-fish pen.' The common British species (*L. vulgaris*) is used as bait by the fishermen, and is often cast upon the shores in great quantity after high winds. In *Sepia*, the shell is calcareous, and is called 'cuttle-bone,' and was formerly used in medicine. This section also includes the extinct *Belemnites*, or Jove's Thunderbolt.

ORDER 2. The *Tetrabranchiata*—have four gills, and are protected by an external chambered shell with simple partitions or septa, perforated by a tube or *siphuncle*. The last chamber of the shell is the largest, and contains the body of the animal. There is no ink-sac. The arms are numerous, and devoid of suckers. It consists of only one living family, the *Nautilidæ*, of which the Pearly Nautilus (*Nautilus pompilius*), which inhabits the tropical seas, is the type. The shell of *N. pompilius* is partitioned off by septa into chambers which gradually increase in size towards the mouth of the shell, where the largest chamber is left for the habitation of the animal, while the other chambers are filled with air. The septa are perforated in the centre by apertures, through which there passes a *vincula siphuncle*, communicating with the chamber where the heart is placed. This order was abundantly represented in past time by such genera as *Ammonites*, *Orthoceras*, and *Ceratites*, which are now entirely extinct.



Ceratites nodosus.

In the *Dibranchiata*, the mode of reproduction is peculiar. The sexes are distinct. One of the arms of the male enlarges, becomes cystic, and spermatozoa are developed in its interior. Thus changed, it is said to be *hectocotylised*. It is then detached, and swims about, ultimately bursting, and depositing the spermatic fluid within the pallial chamber of the female.

VI. SUB-KINGDOM VERTEBRATA.

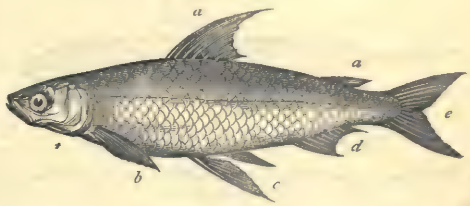
The last and highest division of the Animal Kingdom is composed of animals which have their segments arranged along a longitudinal axis, and exhibit bilateral symmetry. The fundamental character of vertebrates is the possession of an *internal* central axial structure called the *spine* or *vertebral column;* hence the name of the sub-kingdom. This structure may be bony or cartilaginous, or both, and it shuts off the nervous

system from the general body cavity. In a typical vertebrate, such as man, it consists of a series of bones or *vertebræ*, which are articulated together in such a manner as to permit of a greater or less degree of flexibility, and giving attachment to appendages, of which some support and protect important viscera, while others assist in the motion of the animal. Each vertebra has more or less the form of a ring, and when the various vertebræ are articulated together, the whole is termed the *vertebral column*, or backbone. The ring-like apertures in each vertebræ, when thus joined together, form a tube, in which the *spinal cord* is lodged, and from which the nerves which supply the body are given off. The vertebral column is placed dorsally, and serves not only as a surface of attachment for muscles, and a central axis, but also as a protection for the main masses of the nervous system, which are thus also placed dorsally, and are separated by a partition from the general body cavity. The anterior extremity of the spinal column is expanded in a box or case, the *skull* (technically called the *cranium*), in which the *brain* is lodged. The brain is continuous with the spinal cord through an opening in the base of the skull, called the *foramen magnum*. The theory that the skull is composed of a series of vertebræ, whose arches are expanded, and unite to inclose and protect the brain, originated with Goethe, in 1791, on his picking up an old and broken sheep's skull amidst the sandy dunes of the Jewish cemetery in Venice. Lorenz Oken came independently to the same conclusion, and in 1807 published his vertebral theory of the skull. According to Professor Owen, the skull is a continuation of the back-bone, and consists of four vertebræ or segments, corresponding to the four consecutive enlargements of the nervous system which we call the brain. These segments, reckoning them from behind forwards, are termed the occipital, the parietal, the frontal, and the nasal segment. In the embryo of all vertebrates, a structure called the *notochord* (*notos*, back, and *chorde*, string), or *chorda dorsalis*, is invariably present. It generally disappears in the adult, but it is persistent in some fishes. It is a cellular, rod-like structure, situated immediately under the spinal cord, and out of which the vertebral column and some other structures are developed. The general bony fabric of which the vertebral column is the main or central part, is *internal*, an arrangement contrary to that in the lower provinces of creation, where the hard and sustaining parts are *external*. The limbs never exceed four in number, and are turned ventrally, serving for progression, and occasionally for prehension or seizing, but subject to many variations, according to the element in which the animal lives, and the nature of its necessities. By reason of their superior nervous system, vertebrated animals stand decidedly above other provinces in intelligence. With the single exception of the Lancelet, all the vertebrata have red blood, which is due to presence in the blood of an innumerable multitude of minute red, round or oval bodies, called *blood-corpuscles*, about $\frac{1}{3500}$ of an inch in diameter, the fluid in which they float being itself colourless.

This sub-kingdom is divided into the five great classes—Fishes (*Pisces*), Amphibians (*Amphibia*), Reptiles (*Reptilia*), Birds (*Aves*), and Mammals (*Mammalia*). By Professor Huxley, the fishes and amphibia are grouped together under one section, and called *Ichthyopsida*, because at some period or other they breathe by gills. The reptiles and birds he puts into another section, under the name *Sauropsida*, characterised by their never possessing gills, by the skull being articulated to the vertebral column by a single occipital condyle, by the articulation of the lower jaw to the skull through the intervention of a distinct bone (the *os quadratum*), and by the ramus of the lower jaw being composed of several pieces. He retains the name *Mammalia* for the mammals, for the characters of which see Mammalia.

CLASS I.—FISHES.

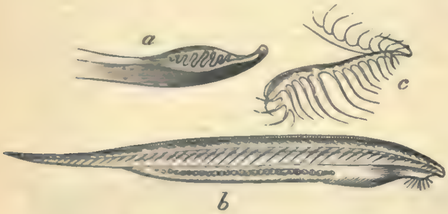
In this class, the animals are wholly aquatic, and breathe by means of gills or *branchiæ*. The heart consists of a single auricle and ventricle. The auricle receives the blood from the system, and propels it into the ventricle, by which it is sent on to the gills, where it is aerated by being exposed to the air contained in the water, and is then distributed throughout the body. The blood is cold—that is, it never rises in temperature above the temperature of the surrounding medium. The four limbs of a typical vertebrate assume in fishes the form of *fins*, and are generally, although not always, all present, the first pair being the *pectoral*, the second pair the *ventral* fins. When the ventrals are placed far forwards, underneath or in front of the pectorals, they are called *jugular* fins. There are other fins, however, which are not placed in pairs, towards the sides, but vertically in the middle line; one or more (*dorsal*) on the back; one or more (*anal*) on the ventral aspect, behind the anus; and one (*caudal*) at the extremity of the tail. These last are called the *unpaired fins*, in contradistinction to the former or *paired fins*. The chief propelling power resides in the *vertically* flattened caudal fin or tail, which is used by the fish in the same way as a single oar is employed in sculling along a boat. The pectoral and ventral fins serve chiefly for balancing the body, while the dorsals and anals, like the keel of a ship, keep it in its proper position. The surface of the body is usually covered with scales. In many species, the gills are covered by a corneous plate, styled the operculum. In those fishes which have a well-formed vertebral column, the individual vertebræ are hollowed on each side, with a bag of lubricating fluid between them, an arrangement which gives great suppleness and agility of movement. They are nearly all oviparous, and some are amazingly productive. The



Fish:
a, dorsal fins; *b*, pectoral fin of one side; *c*, ventral fins; *d*, anal fin; *e*, caudal fin, or tail; *f*, operculum.

female deposits her eggs or spawn, leaving to the male the duty of afterwards fertilising them. The teeth of fishes are chiefly designed to serve as means of seizing prey. They are not only placed on the jaws, but also on the tongue, palate, and other parts of the passage leading to the stomach. The lungs of other vertebrates are represented in fishes by the *swimming-bladder*, which is of service in floating the animal.

ORDER I. The *Pharyngobranchii*—includes only a single genus, the *Amphioxus lanceolatus*, or Lancelet, which differs remarkably from other fishes. It has neither skull nor brain; the lower jaw and limbs are absent. The spinal column exists in its embryonal form. The heart is represented by pulsatile swellings upon the great vessels. The mouth is in the form of a longitudinal fissure, surrounded by filaments, and leads into a pharynx perforated by clefts, which are ciliated, and perform the function of respiration. This singular little fish, which measures about one



Lancelet (*Amphioxus lanceolatus*):

a, mouth, seen from below; *b*, general figure; *c*, hyoid bone, with filaments attached.

inch in length, is found burrowing in the sand on the shores of the Mediterranean. The body is lanceolate; and running along the dorsal surface in the median line is an imperfect crust or fin, which expands at the tail into a lancet-shaped caudal fin.

ORDER 2. The *Marsipobranchii*—have the body cylindrical in form, and destitute of limbs. The skull and spinal column are cartilaginous, and the lower jaw is absent. The mouth is round, and supported by a cartilaginous ring, and adapted for adhering to prey. The skin is soft, with scarcely a vestige of scales. The gills are sac-like, communicating internally with the pharynx, and externally by one or more openings situated on the side of the body near the head. It comprises the Lampreys (*Petromyzon*), characterised by having roundish gill orifices on each side of the neck, and by the possession of a tooth within the cartilaginous ring, with which they tear their

Common Lamprey (*Petromyzon marinus*).

prey. There is a marine species two or three feet long, and other smaller ones which inhabit rivers. The *Myxine* (Hag-fish) is blind, and is found parasitic in the interior of other fish, usually the cod, into which it penetrates by means of its singular curved tooth. In this genus, the nasal sac opens posteriorly into the pharynx.

ORDER 3. The *Teleostei*, or 'osseous' fishes have a well-ossified skeleton, and the skull is composed of numerous bones. A lower jaw is present. The gills, which are supported upon bony arches, are tufted and comb-like in shape, and lodged in two branchial chambers, each of which communicates internally with the pharynx, and from which the water passes away by a single aperture (gill-slit), which is covered with a bony operculum. The *bulbus arteriosus*, which is situated immediately in front of the ventricle, is not contractile, and there is never more than a single row of valves separating it from the ventricle. The fins, when present, are supported by rays. The nasal sacs do not communicate posteriorly with the pharynx.

Sub-order (A). The *Malacopteri*—have *soft* or many jointed fins—that is, fins which are supported by bones, which split up longitudinally as they diverge from a common point of insertion. Further, these bones are divided transversely into shorter pieces. A swimming-bladder is always present, and communicates with the gullet. This sub-order is divided into two groups: I. *Apoda*, from which the ventral fins are absent, comprising the well-known *Murænidæ*, or Eel tribe. They are all lengthened in form, have the spine very flexible, the skin soft and thick, and the scales almost invisible. Many of them inhabit rivers, while others are marine, as the Conger, which is from four to six feet long, and destitute of both pectoral and ventral fins. The Common Eel (*Anguilla*) can live for some time out of the water. This is due to the smallness of the gill apertures, which keep the breathing organ moist.

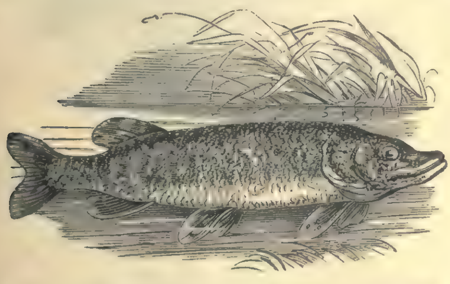
Electrical Eel (*Gymnotus electricus*).

The most remarkable form is the *Gymnotus*, or Electrical Eel. It is a native of the South American rivers. It attains the length of five feet, and can communicate a shock powerful enough to stun men and horses. The electrical apparatus is largely supplied with nerves, and extends throughout the greater part of its body. By giving these shocks, the animal is greatly exhausted, and requires rest and nourishment before it can renew them. In this genus, the anus is placed in front of the gill openings. The second group—namely, the *Abdominalia*—have

the ventral fins attached to the abdomen behind the pectorals. It includes the greater number of the fresh-water fishes. There are five families.

The *Cyprinidæ* (Carp tribe) are all fresh-water fishes. The mouth is shallow, the jaws feeble, and the pharynx strongly toothed. They feed chiefly on seeds and decomposing vegetable matter. One of the finest European species is the Carp (*Cyprinus carpio*), which is imported into England, and thrives well in ponds and lakes. The Barbel and the Cobitis or Loche are allied species well known to anglers. The Gold-fish of China (*C. auratus*), now naturalised in this country, also belong to this family. The *Anableps*, from the rivers of Guiana, has the cornea and iris divided by transverse bands, so as to give the fish the appearance of having four eyes.

The *Esocidæ* (Pike tribe), the most voracious of the fresh-water fishes, are characterised by the absence of fatty matter in the dorsal fin, and by the position of this opposite to the anal fin. The Pike (*Esox lucius*) sometimes weighs forty pounds, and is very destructive to the smaller fishes in the ponds and rivers which it inhabits. The Gar-fish, or Sea-pike, which frequents the British

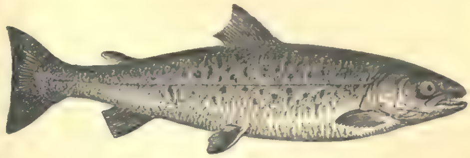


Pike, or Jack (*Esox lucius*).

shores, sometimes attains the length of eight feet. The Mackerel-pike, or Saury, a British species, is gregarious in its habits, and is preyed upon by porpoises and tunnies.

The *Siluridæ* (Sheat-fishes) have no true scales, the skin being either naked or covered with bony plates. They inhabit the rivers of warm climates. The genus *Silurus* have a strong spine in front of the dorsal fin, which can be laid flat or raised perpendicularly, so as to form a formidable weapon. The *Malapterurus electricus* of the Nile and rivers of Central Africa, which attains the length of twelve inches, has electric properties similar to those of the torpedo and gymnotus.

The *Salmonidæ* (Salmons and Trouts) are very extensively, indeed almost universally, diffused over the globe ; some of them being confined to fresh water, and others passing a part of their lives in the sea, but resorting to rivers to deposit their eggs. They are distinguished by the fatty deposition in the dorsal fin. All of this family are clouded with dusky patches when young, and many remain permanently spotted. The flesh of most of them is esteemed as food. The Salmon inhabits the seas of comparatively cold regions, ascending the rivers for the purpose of spawning, at seasons varying with the climate. They swim against powerful streams, and leap up cascades of considerable elevation, and find their way to the brooks and small lakes of lofty mountains. After this operation is accomplished, they return to the sea, followed by the young fish. The best known British species are the Common Salmon (*S. salar*),



Salmon (*Salmo salar*).

the Salmon Trout (*S. trutta*), and the Gray or Bull Trout (*S. eriox*). The Trout appears to vary much in size and colour according to the climate and other conditions of its residence, so that it is difficult to distinguish species from mere varieties. The Common Trout (*Salmo fario*), whose growth is wonderfully rapid, is too well known to require description. The Smelt (*Osmerus*) and Grayling (*Thymallus*) of British rivers, and the Capelin, which is used on the shores of Newfoundland for bait, also belong to this family.

The *Clupeidæ* (Herring tribe) is one of the most important families in the whole class, for the amount of food it supplies to man. The fishes belonging to it resemble the Salmonidæ in many characters, but differ in having no fatty matter in the dorsal fin. They chiefly inhabit the seas of the temperate zone. The Herring (*Clupea harengus*) usually lives in open ocean, but periodically visits the nearest coast in immense shoals to deposit its spawn. There are many species, differing but little from the herring. Thus, the Pilchard is caught on the Cornwall coast, the Sardine on the west coast of France and in the Mediterranean, where the Anchovy, well known for its rich and peculiar flavour, also abounds. The Sprat, Whitebait, and Shad belong to the same family.

Sub-order (B). The *Anacanthini*—have the fins entirely 'soft.' The ventral fins, if present, are brought forward beneath, or even in advance of the pectorals. If the swim-bladder is present, it never communicates with the gullet by a duct. Two groups are included under this sub-order :

1st Group, the *Apoda*, which are destitute of ventral fins. The Sand-eels (*Ammodytes*) belong to this group. They bury themselves in the sand during the ebb of the tide, and are used as bait by the fishermen.

In the *2d Group*, the *Sub-branchiata*, the ventral fins are present. It comprises two families—

Family *Gadidæ* (the Cod tribe) are easily known by the softness of all their fins, and by having the ventrals inserted under the throat, and pointed. To this family belong the Haddock, Whiting, Ling, Pollack, and the Cod itself. Besides being used as food, the oil obtained from their livers is very serviceable in the arts and in medicine.

The second family is that of *Pleuronectidæ* (the Flat-fish or Flounder tribe). The body is compressed from side to side, and margined almost throughout by long dorsal and anal fins. The two flat surfaces—one of which, in the ordinary position of the fish during life, is above, and the other below—are in reality the two *sides* of the fish, differing in several important respects. The bones of the head are singularly twisted, so that both the eyes are placed on one side of the

body, and this, which is always the upper, is dark in its colour, whilst the opposite side is always white. The two sides of the mouth are not equal, and the pectoral fins rarely so. On the other hand, the dorsal fin, which runs along one of the lateral edges, corresponds with the anal, which occupies the other, and with which the ventrals are sometimes united. They frequent the bottom of the sea, and swim along by an undulating motion of the whole body, while the colour of their upper surface usually corresponds closely with that of the ground on which they lie, and thus they escape the observation of their enemies, and are unnoticed by the small fishes on which they prey. The Flounder, Turbot, Brill, Plaice, Halibut, and Sole are the chief species on our

Sole (*Solea vulgaris*).

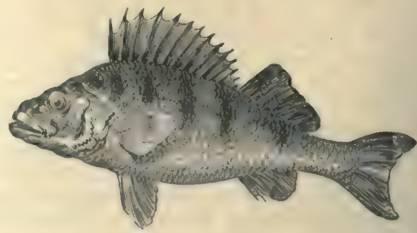
own coasts; they are agreeable and wholesome as food.

Sub-order (C). The *Acanthopteri* (Spiny-finned Fishes)—in which one or more of the first rays in the fins are supported by a 'spiny,' or injointed bony ray. There is no duct to the swim-bladder. The ventral fins are situated on the breast or throat in the neighbourhood of the pectorals. The scales are generally ctenoid or comb-like. This sub-order includes a great number of families:

The *Labridæ* (Wrasse or Rock-fish tribe) are known by the thickness and fleshiness of their lips, whence their name. Those of the genus *Labrus* are called 'old wives;' and this family contains a large number of species, which are principally inhabitants of tropical seas, and they are of but slight direct importance to man. Some of the tropical forms are remarkable for the beauty of their colours.

The *Fistularidæ* (Pipe-mouthed Fishes) are recognised by their very prolonged muzzle. They are chiefly found in warm latitudes, but Sea-snipe (*Centriscus scolopax*) is occasionally found on the Cornish coast as a straggler from the Mediterranean.

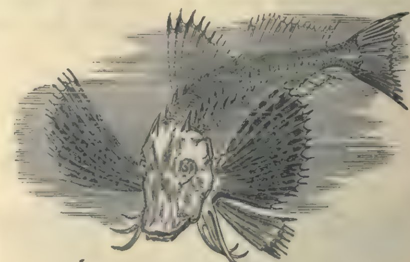
The *Percidæ* (Perch tribe) are numerous in the waters of warm climates, some species inhabiting the rivers, and others the sea. Their bodies are oblong, and covered with hard scales; and the gill-covers are toothed at the margin. The teeth are minute and set together in numerous rows. The ventral fins are generally placed under the pectorals. This family includes the Common Perch (*Perca fluviatilis*), which is found in almost every piece of clear fresh water, and a large number of marine fishes used as food on different shores. Some of the most remarkable are the *Trachinus*, or Weaver, which has a very prolonged and sharp dorsal spine, capable of inflicting a severe injury; the *Polynemus*, or Mango-fish of the Ganges, which has the pectoral fins on each side prolonged into threads thrice as long as the body; the *Uranoscopus* (Star-gazer), so called from the position of the eyes on the top of the



Perch (*Perca fluviatilis*).

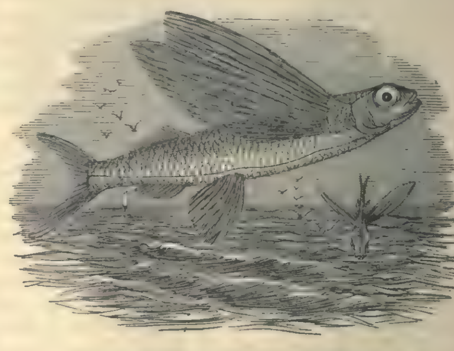
nearly cubical head; the *Mullus surmulletus* (Red Mullet) of British seas, and many others.

The *Triglidæ* (Gurnard tribe) bear a resemblance to the perches, but have the head armed with spines or hard scaly plates. The Gurnards,



Gurnard (*Trigla pini*).

the Sticklebacks, and the *Sebastes*, or Norway Haddock, the spines of which are used by the Greenlanders as needles, belong to this family. The most interesting of all is the *Dactylopterus*, or Flying-fish. This has a kind of supplementary pectoral fin on each side, formed of a membrane stretched over finger-like processes, which in the gurnards are unconnected. By the impulse of these on the surface of the water, the flying-fish can rise several



Flying-fish (*Exocœtus volitans*).

feet into the air, and suspend themselves above the surface for a few seconds, often skimming lightly over it for a considerable distance.

In the *Sparidæ* (Sea-bream tribe), the genus

Sparus has the jaws covered with round flat teeth, like pavement, for grinding down the stony corals, and the hard shells of mollusca on which they principally feed.

The *Chætodontidæ* have the body compressed, and the soft and spinous parts of their dorsal fins covered with scales, so as not to be distinguished from the rest of their body. The *Chætodon rostratus*, a native of India, which has a very prolonged snout, has the faculty of shooting insects with drops of water projected from the mouth, and it then seizes them as they fall.

The next family, *Scomberidæ* (the Mackerel tribe), is one of very great importance to man. It comprises a large number of genera, a vast collection of species, and numberless individuals. The aspect of the Common Mackerel, with its spindle-shaped, beautifully coloured, smooth, and small-scaled body, is well known. It very rapidly dies out of water, and soon becomes tainted. The Tunny (*Thynnus vulgaris*), which frequents the Mediterranean, is a much larger fish, sometimes attaining the length of twenty feet. The *Xiphias*, or Sword-fish, which abounds in the Mediterranean, and often attains the length of fifteen feet, also belongs to the family. It can drive its long-pointed beak into the timbers of a ship. The

Dory (*Zeus faber*).

Dory—remarkable for the filamentous prolongations from its dorsal fins—is much prized by epicures. And lastly, may be mentioned the *Coryphæna*, commonly known as the Dolphin. This is a large and splendidly coloured fish. It has long been celebrated for its change of colour when dying. It swims with great rapidity, and is very voracious, committing great havoc among the flying-fish.

The small family of the *Tænidæ* (Ribbon-shaped Fishes) are remarkable for the lateral flattening of their body. The *Lepidopus argyreus* (the Scabbard-fish) belongs to the family.

The *Mugilidæ* are lengthened and often nearly cylindrical fishes, with a somewhat projecting snout, and a very small mouth placed beneath it. They are gregarious in their habits, frequenting the mouths of rivers in large troops, and constantly leaping out of the water. There are several species found in European seas, but the one best known on the British coast is the *Mugil chelo*, or Thick-lipped Gray Mullet.

The family of the *Anabatidæ*—of which the Climbing Perch of India (*Anabas scandens*) is an example—are remarkable for having the superior pharyngeal bones divided into irregular leaves, placed in the base of the skull, and containing cells among them, in which a supply of water for moistening the gills may be carried, thus enabling the animal to continue respiration out of its proper element. By means of this apparatus, these fishes are enabled to quit the pool or rivulet which constitutes their usual element, and move to a considerable distance overland. They are able not only to traverse plain grounds, but can even climb trees in search of their prey.

The members of the family *Gobiodæ* (or Goby tribe) are known by the thinness and flexibility of their dorsal spines. Many of them are remarkable for producing their young alive. This is the case with the Blenny, of which several species frequent the British shores, living in small troops among the rocks. They are remarkably tenacious of life, and are capable of being kept a good many days in moist grass or moss, but they are of little value as an article of food. One of the most interesting species of this family is the *Anarrhicas lupus*, or Sea-wolf. It inhabits the northern seas, and is often met with on our shores, attaining the length of six or seven feet. It is very formidable in aspect, is remarkably strong, very active, and equally ready to defend itself or attack an enemy. In the *Echeneis remora*, or Sucking-fish, the upper surface of the head is furnished with a series of thin cartilaginous plates, by means of which the animal can attach itself to any kind of surface. It seems to prefer bodies in motion, and is not unfrequently found adhering to large fish, and to the bottoms of vessels, whose course it was once absurdly believed capable of arresting. It is abundant in the Mediterranean. The true Gobies have the ventral fins placed far forwards and united at their bases; they are chiefly remarkable for the *nest* which they construct among the sea-weed for the protection of their young.

The last family, the *Lophiidæ*, have the wrist bones much elongated, upon which the pectoral fins are supported, thus forming a kind of arm. This conformation gives these fish a very strange appearance. One of the most curious is the *Lophius piscatorius* (Angler or Fishing-frog) of the British seas. It derives its name in part from its wide gaping mouth, which is placed transversely, and furnished with many sharp-curved teeth, and

Angler (*Lophius piscatorius*).

in part from the peculiar manner in which it angles for its prey. There are some curious appendages to its head, which terminate in long, round, and rather brilliant filaments. The animal, which sometimes measures four feet in length, lurks in the mud, and puts these appendages in vibration; they are mistaken for worms by small fishes, which they attract, and these are gulped down the capacious maw of the lophius. To such an extent is this voracity carried, that the angler

is often an article of value for the fish which it has in its stomach, although its own flesh is but little worth.

Sub-order (D). The *Plectognathi*—approach the Cartiligines in many points of organisation; principally, however, in the slow ossification of the skeleton, and the imperfect structure of the mouth. They derive their name from the union of the upper jaw to the skull; so that its motion is obtained, not from a distinct joint, but by the mere flexibility of the half-ossified cartilages. The gill-lid is concealed under the thick skin, with only a small opening; the ribs are scarcely developed; and there are no true ventral fins. This order contains two families:

The family of the *Sclerodermata* contain fishes which are remarkable for their hard and granulated skins. They have the head prolonged into a muzzle: at the extremity of this is the mouth, which is armed with a series of distinct teeth. The *Ostracion* (Trunk-fish), which is found in the Indian and American seas, has the whole of the body except the tail covered with an inflexible suit of bony armour, composed of bony plates. The *Balistes* (File-fishes) have the dermal skeleton in the form of small grains, leaving the skin a certain amount of flexibility. They are principally inhabitants of warm seas.

The *Gymnodonta* (Naked-toothed fishes) are distinguished by having the jaws covered with an ivory-like substance arranged in small plates, which are reproduced as soon as destroyed by use. They live on crustacea and sea-weed. The most remarkable species of this family are the Spinous Globe-fishes, *Diodon* and *Tetraodon*, which have the power of blowing themselves up like balloons, by filling with air a large sac which nearly surrounds the abdomen. They are defended by spines over their whole surface, which are erected as they are inflated. The *Sun-fish* has a body of somewhat similar form, but incapable of inflation; from the shortness of its tail, it looks like the anterior half of a fish cut in two in the middle. There are only two British species of sun-fish (*Orthagoriscus*), and some specimens have been known to weigh 300 pounds.

Sub-order (E). The *Lophobranchii*—are a small

Hippocampus brevirostres.

group, which have the gills arranged in tufts in pairs upon the branchial arches. The swim-bladder is destitute of an air-duct. The body is covered, not with small scales, but with shields or plates, which often give it an angular form. In general, they are of small size, and almost without flesh. The *Syngnathus* (Pipe-fish) possesses a long tubular snout. It is peculiar for the protection it affords to its young. The eggs are conveyed into a sort of pouch under the body of the male, and are hatched there, the young fry afterwards finding their way out. Some of these are found in the British seas; as are also the *Hippocampi*, commonly called 'sea-horses,' from the resemblance of the upper part of the body to the head and neck of a horse in miniature. The tail is prehensile, and they climb or hold on to the stalks of marine plants by its means.

ORDER 4. The *Ganoidei*—are a group of which there are few living representatives at the present day, but they attained an enormous development during the Palæozoic period, when they were represented by such genera as Pterichthys, Coccosteus, Pteraspis, and Cephalaspis, from the Old Red Sandstone. In this group of fishes, the endo-skeleton is very imperfectly ossified; in fact, in many of the fossil forms the skeleton was entirely cartilaginous. The exo-skeleton consists of plates or scales, which are composed of an upper layer resembling enamel, and termed *ganoine*, and an under layer of true bone. These plates in some genera are of a rhomboidal form, and delicately sculptured, and being placed edge to edge, afford an efficient yet flexible investment for the soft parts within. The ventral fins are usually present, but they are placed far back near the anus. In some recent forms, such as the Polypterus, and in many extinct forms, the paired fins have their fin-rays arranged round a central lobe. Those fishes with fins so constructed are 'fringe-finned,' and belong to the division *Crossopterygidæ* of Huxley. The tail is generally unequally lobed, when it is said to be 'heterocercal.' The gills have the same structure as in the *Teleostei*. The swim-bladder possesses an air-duct which communicates with the pharynx. The *bulbus arteriosus* is rhythmically contractile, and is separated from the ventricle by several rows of valves. The intestine is furnished with a folding of its mucous membrane, so as to form a spiral valve.

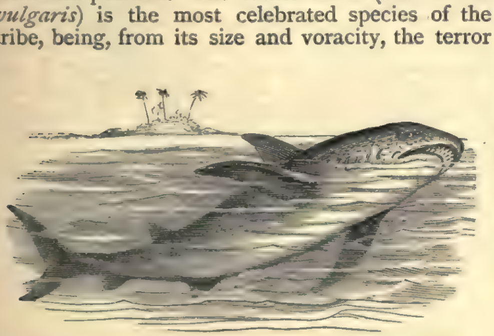
The *Lepidosteus* (Bony Pike) of the rivers and lakes of North America, and the *Polypterus* of the Nile, are recent examples. The former has the jaws prolonged into a long narrow snout, and the tail heterocercal; the body is protected by transversely arranged rows of ganoid plates. The latter has its dorsal fin broken up into a series of small fins, each of which has a strong spine in front, and a soft fin attached to it posteriorly. The *Sturionidæ*, or Sturgeons, also belong to this order. In them the notochord is persistent, and the tail is heterocercal. They are found in the Black and Caspian Seas, and ascend the rivers for the purpose of spawning. They are extremely valuable to man, their roe furnishing the caviare so much esteemed in Russia, and the air-bladder furnishing isinglass. The Common Sturgeon (*Accipenser sturio*) of the British coasts is about six feet long; but the Beluga (*A. huso*) of the Caspian Sea measures fifteen feet in length. The *Spatularia* (Paddle-fish) of North America is a nearly allied form.

ORDER 5. The *Elasmobranchii*, including the Sharks and Rays, correspond pretty closely with the Cartilaginous Fishes of Cuvier. The skull is a simple cartilaginous box, without sutures. The vertebral column is more or less cartilaginous, and the exo-skeleton is 'placoid' in its character—that is, consists of bony grains or tubercles scattered throughout the integument. The gills are peculiar, in that the branchial laminæ are fixed like the leaves of a book to partitions which divide the gill-chamber into a series of pouch-like spaces, which communicate internally with the pharynx, and externally by one or more apertures placed on the side of the neck, there being no operculum or branchiostegal rays. The structure of the intestine and of the heart is the same as in the *Ganoidei*.

Sub-order (A). The *Holocephali*—including the *Chimæra monstrosa*, which often accompanies herring shoals, hence called the 'King of the Herrings.' It has the mouth terminal in position, and only a single gill aperture on each side of the neck, covered by an imperfect operculum.

Sub-order (B). The *Plagiostomi*, which have the mouth transverse, and placed on the under surface of the head. There are several apertures representing gill-slits on each side of the neck. It includes the Port Jackson Shark (*Cestracion Philippi*) of the Australian seas, with its curious pavement-like teeth, adapted for crushing the crustacea and mollusca upon which it feeds. The *Selachii*, including the true Sharks and Dog-fishes, also belong to this group. They are distinguished from other fishes by many peculiarities: in several species, the young are produced alive, the eggs being hatched within the body of the parent; and in others, the eggs are inclosed in a horny casing, which has often long tendril-like appendages, that coil around and attach the mass to other bodies. This is the case with the eggs of the common Dog-fish and Skate of our coast, the receptacles being vulgarly known as 'sea-purses.'

The sharks are distinguished by their lengthened spindle-shaped bodies, by the gill-slits being placed laterally on each side of the neck, and by the fact that the pectoral fins have the ordinary form and position. The White Shark (*Carcharias vulgaris*) is the most celebrated species of the tribe, being, from its size and voracity, the terror



White Shark (*Carcharias vulgaris*).

of mariners in the seas it inhabits. It frequents warm latitudes, but has occasionally visited the British shores. It has been known to attain a length of thirty feet, and the opening of the jaws in the largest individuals is sufficient to admit with ease the body of a man. As the mouth is placed in the under surface of the head, the fish cannot bite while in the act of swimming forwards, so that a dexterous person has been known to defend himself from its attack. The teeth are triangular and lancet-shaped, with acute points and edges, and form several rows; they are not fixed in the jaw itself, but in a muscular membrane, by which they are erected and made to project when in use, lying flat in the intervals. As the foremost are torn away, they are replaced with others, which are brought up from the rows behind. The Blue Shark (*C. glaucus*), which frequents the Mediterranean, is not unfrequently a source of great trouble to the fishermen of our coasts, on account of the injury which it does to their nets. It sometimes attains the length of eight feet. The *Zygæna malleus*, or Hammer-headed Shark, is a remarkable genus, so named from the projection of the head at each side in the form of a double-headed hammer, with an eye in the middle of each extremity. The Fox-shark (*C. Vulpes*) is a British species. It is also called the Thrasher, from the use it makes of its tail, the upper lobe of which is elongated and very powerful.

The last group, the *Batides*, including the Rays, and Skates, and Thornbacks (*Raia clavata*), are remarkable for extreme horizontal flattening of the body, on the under surface of which, a little behind the mouth, the gill-slits are disposed in two rows. They abound rather in temperate than tropical seas. The eyes are placed on the back or upper surface. The most interesting of all is the Electric Ray or Torpedo of the Mediterranean. It possesses an electrical apparatus, by which it can give a smart shock to any animal it touches. The flesh of the ray is wholesome. The skin of some of them is employed in the arts for polishing, and from that of others shagreen is made. In the *Pristis*, or Saw-fish, the body is not flattened like the typical rays, but bears a resemblance in its form and general characters to the sharks. Its snout is extended like the blade of a sword, with strong and cutting tooth-like spikes on both sides. This fish sometimes measures from 12 to 15 feet, and will attack and inflict dreadful wounds even on large whales. Of the *Scylliidæ*, or Dog-fishes, three species are known on our coasts. They are distinguished from the true sharks by their oviparous reproduction. Their skin is used by cabinetmakers as a fine rasp, under the name of 'fish-skin.'

ORDER 6. *Dipnoi*—including only the singular Mud-fishes (*Lepidosiren*) of the Gambia and the Amazon. They are peculiar in that they exhibit

Lepidosiren (*Lepidosiren annectans*).

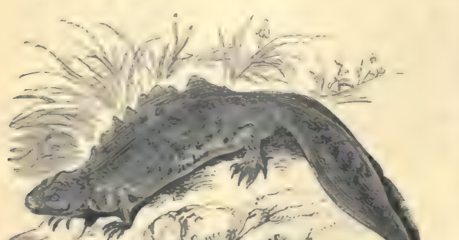
a distinct transition between the Fishes and the Amphibia. They inhabit marshy places, and are able in the dry season to bury themselves in the mud, there remaining dormant until the return of the rainy season.

CLASS II.—AMPHIBIA.

This class was included by Cuvier along with the Reptiles, but there is sufficient reason for separating them into a distinct group of equal importance. They may be regarded as intermediate in their structure and in their habits and mode of life, as well as in many of their forms, between Fishes and true Reptiles. To the former they are allied, in that at some period of their life they breathe by gills, but differ from them in always possessing lungs in the adult condition. Their limbs are never in the form of fins. The skull articulates with the vertebral column by two occipital condyles, and the heart consists of two auricles and a single ventricle. From the arterial and venous blood being mixed in the ventricle, the body is nourished by imperfectly oxygenated blood. They are, like Fishes and Reptiles, cold-blooded animals. They all undergo a metamorphosis after their expulsion from the egg. At first, they possess gills, and are water-breathing animals; but in the adult state they invariably possess lungs. In some genera, the gills disappear as the lungs are developed; but in other cases, both gills and lungs are permanently retained throughout life. As in Reptiles, the gut, and the ducts from the kidneys and generative organs, open into a common cloaca.

ORDER 1. *Ophiomorpha* (serpent-forms)—including one genus, the *Cæcilia*, Blind Newt, or Naked Serpent. It is snake-like in form, and destitute of limbs. The eyes are exceedingly small, and are nearly hidden under the skin. It is a native of South America, Guinea, and Ceylon.

ORDER 2. *Urodela*, or Tailed Amphibians.—The animals included under this group retain their tails in the adult condition, and their skin is soft, and destitute of scales. In one section (*Amphipneusta*), both gills and lungs are retained throughout life—for example, the Proteus of the caves of Illyria, and the Siren or Mud-eel of the rice-swamps of South Carolina. In the second section, the gills disappear at maturity, and the animals breathe by lungs alone. This section includes the Land and Water Salamanders. The Tritons, or Aquatic Salamanders,



Warty-newt (*Triton cristatus*).

commonly called Newts, have their tail vertically compressed, and are oviparous. They pass the greater part of their life in the water. They possess the remarkable power of reproducing limbs that have been cut off. The anterior limbs are developed first in the Salamanders, the reverse of what takes place amongst the frogs. Three species are indigenous to Great Britain. The Land Salamanders (*Salamandra*) are distinguished from the former by the cylindrical form of their tail, and by their producing their young alive. All these forms are easily distinguished from the Reptiles by always possessing gills at the earlier period of their life, and by the soft, smooth, naked skin.

ORDER 3. The *Anoura*, or Tail-less Amphibians, including the Frogs and Toads. The adult is destitute of both gills and tail, both of which structures exist in the larva. Four limbs are always present. The larvæ are known as 'tadpoles,' which have a round head, a fish-like tail, and breathe by gills. Ultimately, the tail disappears, limbs are budded forth (the posterior pair first), and the gills are replaced by lungs, so that the adult is an air-breathing animal.

Family *Ranidæ*, or Frogs (*rana*, a frog). They are so well known that a description of them seems unnecessary. They always possess teeth in the upper jaw. They are of a yellowish-brown colour, with black spots, and their power of leaping is well known. As there are no movable ribs to expand the thorax, the mode of breathing is peculiar. The animal closes its mouth, and fills it with air taken in through the nostrils; the nostrils are then closed, and by the compression of the muscles of the throat and cheeks, the air is propelled forcibly into the lungs. The animal would be choked if the mouth was held open. No doubt, the skin also aids in the process of respiration. Their feet are webbed, and suited for swimming. Of the European species, the Edible Frog (*R. esculenta*) is the one most approved of on the continent for culinary purposes. The *R. temporaria* is the only species indigenous to Britain. The Tree-frogs (*Hylæ*) of America have their feet provided with suckers, which enable them to climb trees in pursuit of their food—insects.

Family *Pipida*, distinguished by the absence of the tongue, including the ugly *Pipa Americana*, or Surinam Toad, which is eight inches long in the tadpole condition, while the perfect frog is only three in length. It is a native of Brazil and Surinam.

Family *Bufonidæ* (Toads) in which the jaws are destitute of teeth. They are of a dull, cadaverous appearance, and their bodies are covered with warts. They have a swelling above each eye, from which a fetid, milky secretion is expressed. Two species are found in Britain, the Common Toad (*Bufo vulgaris*), and the Natterjack (*B. calamita*). They seldom frequent the water but for the purpose of depositing their eggs. The tongue in these animals, as in the frogs, is fixed to the *front* of the mouth, and *free behind*.

CLASS III.—REPTILIA.

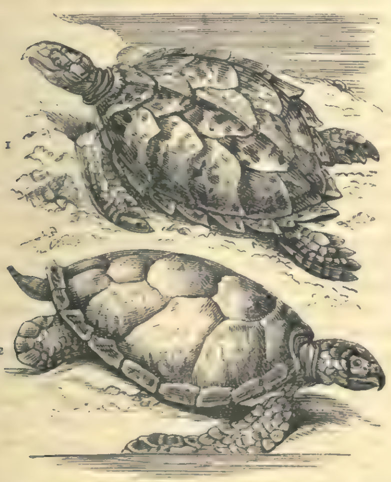
The Reptilia, or creeping animals (*repo*, I creep), though in outward form many of them resemble the Amphibia, yet in intimate structure they are more closely allied to birds. They are oviparous, and many of them are covered by hard scales, but never by feathers. They never breathe by gills, but always by lungs. The heart consists of two auricles and a ventricle, so that only a portion of the blood returned by the veins is propelled

through the lungs, the greater part passing again into the circulation without being aerated. Hence it is that the blood is cold, the digestive powers weak, and their vitality low, so that their functions may be suspended for a considerable time without apparent injury to the animal. The skull is articulated to the vertebral column by a *single* occipital condyle.

ORDER 1. *Chelonia.*—In typical species, the ribs are expanded so as to form but one bony plate, having no flesh outside, but being covered with horny plates, secreted from the skin like hair or nails; the breast-bone is similarly expanded into a plate, covering the whole of the lower surface, and joining the edges of the upper plate; so that the animal may be said to be sheltered in a box formed of its bones. Within this box, the upper plate of which is named the *carapace*, and the lower the *plastron*, the animal can even withdraw its head and feet, and thus set most enemies at defiance. There are no teeth, and the edges of the jaws are sheathed in horn, so as to form a kind of beak.

The family *Chelonidæ* (Turtles) are designed for sea-life, and their extremities take the form of paddles. They swim with great ease, and only come to land to deposit their eggs, which they do thrice a year, laying about 100 at a time. They feed chiefly on marine plants. They are sometimes five feet in length, and weigh 800 pounds. The *Chelone midas* (Edible or Green Turtle) of the tropical seas of America, is noted for the delicious food which it yields. Ascension Island is one of their favourite retreats.

The *Chelone imbricata* (Hawk's-bill Turtle) is a



1, Hawk's-bill Turtle (*Chelone imbricata*); 2, Green Turtle (*Chelone midas*).

smaller species, and is remarkable for the imbricate beautifully marked horny plates covering its carapace, which yields the *tortoise-shell* of commerce. These plates do not join at the edges like those of land-tortoises, but overlap each other like the scales of other reptiles. The finest tortoise-shell is brought from the Indian Archipelago.

The *Chelone* or *Sphargis caretta* (Leathery Turtle) has the carapace covered by a leathery skin in place of horny plates. This animal inhabits the Mediterranean as well as the Atlantic and Pacific Oceans.

The family of the *Emydæ* (Terrapenes) and the *Trionycidæ* (Mud Turtles) have the feet furnished with toes, and being partly webbed, they are useful for swimming. The Snapping Turtle (*Trionyx ferox*) of America is capable of biting through a stick half an inch in diameter. The *T. Niloticus* is highly serviceable in the Nile and other rivers in destroying young crocodiles and alligators. They are all inhabitants of fresh water.

The *Testudinidæ* (Land Tortoises) have the feet furnished with short nails, and adapted for walking on firm ground. Their armour is thicker and

Common Land Tortoise (*Testuda græca*).

stronger in proportion to their size than the aquatic species. They are vegetable feeders. The *T. græca* of Spain is often kept as a domestic pet.

ORDER 2. *Ophidia*—have an elongated cylindrical body, covered with scales, but destitute of limbs, though in some serpents rudimentary posterior limbs can be traced, but these are of no use for progression. The ribs are exceedingly numerous, and very movable, and their pointed extremities are attached by muscles to the abdominal scales, or 'scuta,' of the integument. By this arrangement, the animal moves along on the points of its ribs, the whole being facilitated by the very movable spinal column. The tongue is forked, and there is no eyelid, the eye being covered with a glassy capsule, within which the eye moves freely. All are furnished with teeth, which never occupy distinct sockets, but are united to the jaw, and are arranged either in two or three rows. The two halves of the lower jaw, which are composed of several pieces, are united in front by ligaments and muscles, which permits of their being separated to a considerable distance, so that, though the head is small, these animals are enabled to swallow their prey entire. They remain torpid during winter, and each season cast their skin.

Sub-order 1. *Viperina*, or Venomous Snakes—have a pair of perforated poison-fangs in the upper jaw, which can be erected or depressed at will. When the animal is irritated, they are unfolded, and struck into the victim, the poison being at the same time ejected by the action of the muscles of the jaws. The matter is poisonous only when introduced into the blood. The *Viperina* comprise the Rattlesnakes (*Crotalidæ*) of America, which are distinguished by a pit behind each nostril, and by the presence of the rattle. They are highly venomous, but they will not attack man unless when trodden on or provoked. The extremity of the tail in *Crotalus horridus* is furnished

with a series of horny epidermic rings, known as the 'rattle,' which produces a rattling noise when the animal moves, hence the name. Some

Common Viper, or Adder (*Pelias berus*).

measure five or six feet in length, and are as thick as a man's arm. Their food consists of birds and small animals. The *Viperine Snakes* are distinguished from the former by a broader head, by the absence of the rattle, as well as the cavities behind their nostrils. They are entirely confined to the Old World, in the warm countries of which they are very abundant. The Common Viper (*Pelias berus*) can inflict a dangerous bite, and is the only venomous reptile found in Britain.

Sub-order 2. The *Colubrina*—in which the maxillary bones are armed with solid conical teeth. If fangs are present, they are only grooved on one side. They are for the most part harmless, but some of them are extremely venomous. This sub-order may be divided into two sub-orders:

(*a.*) *Innocua*, or Harmless Snakes, in which there are only solid teeth on the maxillæ. The *Coluber natrix* (Ringed Snake) of Britain, and the *C. constricta* (Black Snake) of North America, are perfectly harmless. The former is tolerably abundant in Britain, and is a very pretty little creature, about three feet in length. It is of a pale olive colour, spotted in black on the sides, and immediately behind there is on each side a yellowish spot, which gives to the animal its common name of Ringed Snake.

The *Boa Constrictors* of tropical America have the under part of the body and tail covered with transverse shields. Many of the species exceed twenty feet in length, and they can swallow even sheep and oxen. This they effect by coiling themselves round the body of the victim, and crushing it till every bone is broken. They then moisten it with saliva, and proceed to swallow it. The *Pythons* are inhabitants of the Old World, and many of them, from their size and great muscular power, are amongst the most formidable of all Ophidia.

(*b.*) In the group *Venenosa*, which have grooved fangs placed in front of the upper jaw, and solid teeth behind them, are included some of the most venomous of all snakes. The most formidable of these is the Hooded Snake, Cobra di Capello (*Naja tripudians*) of India, the snake usually carried about by the Indian snake-charmers, the bite of which is fatal within an hour. The *Hydrophidæ* (Water-serpents) have a vertically compressed tail, and so can swim with great facility. They are very venomous, and are chiefly found in the rivers and seas of the East Indies.

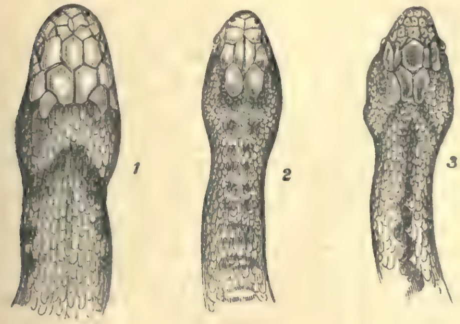
Cobra di Capello (*Naja tripudians*).

ORDER 3. The *Lacertilia*—comprising the Lizards, which have a lengthened body, terminating in a tail, and covered with small scales. Eyelids are present in all with the exception of the *Geckotidæ*. As a general rule, four limbs are present, although the Blind-worm or Slow-worm (*Anguis fragilis*), which belongs to the family of the *Scincidæ*, has no external appearance of limbs, although the bones of the pelvis and shoulder exist in a rudimentary condition under the skin. It is serpentiform, and quite harmless, and when alarmed, its muscles become so rigid that the tail can be broken off. In the course of a year, however, this member is replaced. It is found all over Europe, and feeds upon insects, slugs, &c. Nearly allied to the former are the *Amphisbænidæ* (Double-walkers). They can move forwards or backwards with equal facility. They are small harmless animals, found in the warmest parts of South America. These serpentiform *Lacertilia* are at once distinguished from the *Ophidia* by the structure of the lower jaw, the two halves of which are united in front by a suture so as to restrict the gape.

In order that any one may be able readily to make out the differences between the three snakes indigenous to Great Britain, and thus perhaps be saved from the danger that might accrue from handling or incautiously approaching a viper, mistaking it for the harmless ring-snake or coronella, we give an illustration and brief description of the heads of the three species.

1. The common ringed snake has a somewhat almond-shaped head, covered with broad plates or shields. It has invariably a yellow collar at the back of the head, the yellow colour being made more apparent by a jet-black collar behind it. This black collar does not in every case extend right across the neck, but varies in different specimens. The eye is rather prominent, of a hazel colour. The prevailing colour of the back and sides is dusky brown. The centre line of the back is marked with a double row of small black spots, which extend from the head to the tail, and from these rows, lines made up of similar dots stripe the sides.

2. The head of *Coronella lævis*, it will be at once evident, is exceedingly small, compared with



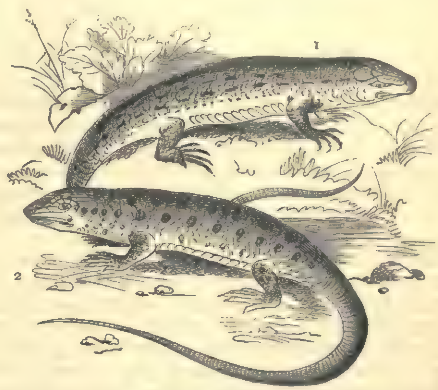
1, The Common Ringed Snake (*Coluber natrix*); 2, The Small-crowned Smooth Snake (*Coronella lævis*); 3, The Common Viper or Adder (*Pelias berus*).

the other two; moreover, it is rounder, and more like the head of a lizard, and carried in a more erect position than the head of the ring-snake. The plating on the top of the head is very like that of the ring-snake, but the lateral plates differ from those of the viper. One marked peculiarity in the head of *Coronella lævis* is that it is beautifully iridescent, and of bronze green colour. There is but a very imperfect V-mark—not at all distinct, like the brand on the viper, being broken or imperfect at the sharp terminal angles, while that on the viper is complete. The general colour of the skin is brown; and it is remarkable for its almost polished smoothness, which gives the reptile its name, *lævis*. Two rows of dark spots run along the sides of the back, which at once distinguish it from the viper, with its zigzag marking. The belly is a brightish orange colour.

3. The head of the viper, it will be observed, is not shaped like the head of the snake; it is perfectly flat. The viper has no collar encircling the neck, but instead the letter V distinctly marked on the back part of the head, as will be more plainly seen by reversing the illustration. It really would almost appear that nature had branded this, the only poisonous reptile inhabiting our land, so that people might the more easily recognise and avoid it, with V, the first letter in the name viper. Continuing from this V-marking, a diamond-shaped pattern of a dark colour extends along the whole line of the back. The general colour of the body is extremely variable, being influenced by local conditions.

With respect to its dangerous properties, Mr Bell remarks: 'In this country, I have never seen a case which terminated in death, nor have I been able to trace to an authentic source any of the numerous reports of such a termination. At the same time, the symptoms are frequently so threatening, that I cannot but conclude that in very hot weather, and when not only the reptile is in full activity and power, but the constitution of the victim in a state of great irritability and diminished power, a bite from the common viper would very probably prove fatal. The poisonous fluid is perfectly innocuous when swallowed. Dr Mead and others have made this experiment, and never experienced the slightest ill effects from it. It is, however, clear that there would be danger in swallowing it were any part of the mouth, the throat, or the œsophagus in a state of ulceration, or having an abraded surface.'

The family of the *Lacertidæ* (Lizards) have four limbs, terminated by five toes of unequal lengths. Their tongues are long, slender, and protrusile. Their bodies are covered with scales, and the head and abdomen with large regular plates or 'scuta.' They are terrestrial in their habits, as their rounded tail indicates. They vary from five to thirty inches in length. They feed upon frogs, insects, and small mammals. The Scaly Lizard (*Zootoca vivipara*), which is viviparous, whence its specific name, is found abundantly in this country on dry banks and sandy heaths, where it may be observed basking in the sunshine, watching for its insect prey. The *Lacerta agilis*



1, Viviparous Lizard (*Zootoca vivipara*); 2, Sand Lizard (*Lacerta agilis*).

(Sand Lizard) is found in England, and the *L. viridis* (Green Lizard) is common in Jersey.

The *Varanidæ* (Monitors) are closely allied to the former, but differ from them in having the head and abdomen covered with ordinary scales. They sometimes measure six feet in length—for example, the *Varanus Nilotus* of Egypt. They are also called Monitors, because they warn each other of the approach of an enemy by a shrill whistling sound. They are confined to the Old World.

Family *Iguanidæ* (Iguana, or Guana Lizards) are distinguished from the true lizards by a short and thick tongue, with the extremity very slightly cleft. It contains several genera. Iguanas, properly so called, are covered with small scales, and they have a dorsal crest and a compressed tail, and are confined to the New World. A large thin fold of skin, or dewlap, hangs from under the throat. Each jaw has a range of triangular teeth, with finely sharpened edges, and a double row also on the palate. They feed upon vegetable substances, and live chiefly upon trees. They sometimes measure four feet in length; and both their flesh and eggs are esteemed as delicacies. One of the most remarkable American species is the Basilisk (*Basiliscus Americanus*), which, although perfectly harmless, is one of the most forbidding of reptiles. It is distinguished by a mitre-shaped crest on the top of its head. The

Amblyrynchus cristatus of the Galapagos Isles, first described by Mr Darwin, is partially aquatic in its habits, spending the greater part of its time in the sea.

A gigantic fossil form, the Iguanodon, characteristic of the Wealden Period, had teeth closely resembling the Iguana of the present day. It attained the length of fifty feet. More remarkable than the iguanas is the Flying Lizard (*Draco volans*) of the East Indies. It is a small animal, possessing a membrane at its sides, stretched over the false ribs, by which it can float, though it has no true power of flight, as upon a parachute, from one tree to another.

Flying Lizard (*Draco volans*).

The *Geckotidæ*, or Nocturnal Lizards, have the toes terminating in little suckers, enabling the animal to creep up vertical walls, and along ceilings, like the flies upon which it feeds. They have a flattened body and a broad head, which, aided by their sombre colour, gives them a disagreeable appearance. They are timid and harmless, and are common in the warm climates of the Old and New World. Like the *Iguanidæ*, they constitute an exceedingly numerous family.

Family *Chamæleonidæ* (Chameleons), which includes the Common Chameleon (*C. Africanus*), are animals of small size, with a prehensile tail. They are readily distinguished from other lizards by having climbing feet, and by the fact that the eye is covered by a circular lid, which is perforated by a small opening opposite the pupil. They are natives of the Old World, and live in trees, which they seldom leave. Their prey, consisting of flies and insects, is taken by darting out the glutinous tongue, which is terminated by an adhesive disk. They are also remarkable for the power they possess of changing their colour.

Chameleon (*Camæleo Africanus*).

ORDER 4. *Crocodilia* (Crocodiles)—are inhabitants of the rivers and fresh waters of equatorial countries. They are formidable animals, and attain the length of twenty or thirty feet. The head is large, and each of the lengthened jaws is furnished with a single row of teeth, which are implanted in distinct sockets. The back and tail are covered with strong dermal plates, permitting of easy motion of the body and limbs. The back is impenetrable to a musket-ball. On land, the motion of the animal is slow, because the legs are short, and the feet are palmated; but in water it moves rapidly, using the tail as a powerful oar. The tail, with its serrated ridge of scales, is a formidable weapon of offence and defence. These animals usually feed upon decayed carcasses that may come in their way, and are thus of considerable service in the hot countries which they inhabit. The eggs, which are about the size of those of a goose, are deposited in the sand, and hatched by the sun. There is only a single genus in this order containing three species —1. The true *Crocodile*, which abounds in the Nile; 2. The *Alligator*, found in the rivers and swamps of North and South America; and 3. The *Gavial*, which inhabits India and the islands of the Eastern Archipelago.

Gavial (*Gavialis Gangeticus*).

Fossil Reptiles.—The *Ichthyosaurus*, from the Lias and Oolite strata, was a marine animal, sometimes twenty feet long, possessing the vertebræ of a fish, with paddle-feet, like those of a turtle, and a crocodile-like head, armed with sharp and formidable teeth. The *Plesiosaur* was a smaller animal, with a neck of extraordinary length, and a small head. But the most singular fossil saurian is the *Pterodactyle*, which had the last digit of the fore-limb extraordinarily lengthened. It was furnished with a pair of wings, like those of a bat, and thus is supposed to have been able to fly through the air in pursuit of its prey.

CLASS IV.—AVES, OR BIRDS.

These are oviparous vertebrates, with a complete double system of circulation, with its proper consequence of warm blood. The skull is articulated

to the vertebral column by a *single* occipital condyle. The young are hatched and nurtured by the parent. Their body is covered with *feathers*, instead of hair or wool; and, as a rule, the fore-limbs are in the form of wings adapted for flight, but they are never used for prehension. The lungs are fixed in the chest, and the air-tubes open on the surface of the lungs into *air-cells*, scattered throughout the body. By this organisation, they can increase or diminish their density, so as to range over the aerial regions with ease and celerity. The bones of birds are singularly light, and exhibit a greater degree of hardness than in any other vertebrate. The lightness is due to the marrow being replaced by air, and the hardness to the presence of a large proportion of phosphate of lime. The eye is generally so constructed that they can see objects far and near with almost equal clearness. Their posterior extremities serve as the sole support of the body on the ground. Most commonly the feet exhibit four toes, of which one is directed behind, and three in front. In the single posterior toe, the number of joints is two; in the external, five. The toes are terminated by claws, which are used for different purposes. Birds have no teeth, and therefore cannot masticate their food, which is either torn by the beak or swallowed whole, and is reduced to a soft state in the stomach. The plan of the digestive system most usual in this class is that which is exemplified in the common fowl. The stomach consists of three cavities: the first being formed by an expansion of the gullet, which produces a bag or chamber known as the *crop*. In this receptacle the food is stored up, and transferred by degrees to the second or membranous stomach, where it is softened by the action of the gastric juice. It is then conducted to the *gizzard*, or third cavity, in which the process of digestion is completed. This last stomach presents modifications varying with the nature of the food upon which the bird subsists. If it feeds on grain, the sides of this stomach are of considerable thickness, and are moved by powerful muscles, which act as a mill in grinding down the food; but in those species which subsist on animal substances, or soft herbage, the muscles are reduced to extreme delicacy. In many cases the process of digestion is promoted by the swallowing of small pebbles, which, being brought into contact with the food in the gizzard by the muscular action of the stomach, produce an effect similar to that of teeth, and in some measure serve the purpose of these agents.

The change of the plumage, termed *moulting*, generally takes place annually; while with some species a partial casting of the feathers occurs also at the breeding season. Many birds migrate from one latitude to another, chiefly for the sake of obtaining a better supply of food. The summer immigrants that visit our island, as the swallow, the rail, the cuckoo, are from tropical regions; while all winter visitants, as the Swan and Wild Goose, come from the north. Under the direction of their highly developed instinctive powers, the place for their nests appears to be selected, their material collected, the nests themselves built, the young reared in them, and their migrations performed.

Many birds are capable of domestication, and in this we see an obvious approach towards that higher form of attachment to man which is exhibited by many species among Mammalia. Birds are of great utility to man, not only as an article of food, but also by keeping in check noxious animals; and in consuming carrion and other refuse. A good classification of birds is still a desideratum. Various classifications have been proposed, but the one given here is that generally employed. In the meantime, it must be looked upon as merely provisional, since it is founded upon *habit*, and not upon anatomical characters or *structure*. All true classification must be founded upon structure.

Natatores.

ORDER I. *Natatores*, or Swimmers, are adapted to an aquatic life, and have the toes united by a membrane or web, the legs short, and placed behind the point of equilibrium. The body is closely covered with feathers, and coated with a thick down next the skin. In this order we find the nearest approach to reptiles which is to be found amongst birds.

The *Alcidæ* (Auk tribe) exhibit the most remarkable adaptation of the structure of the bird to an aquatic life, with which the entire order presents us. This is best seen in the Penguins (*Aptenodytes*), whose wings are very small, and covered with mere vestiges of feathers, resembling scales; so that they serve as admirable fins or paddles, but are totally useless for flight. The feet are placed very far back, so that, when upon land, the bird stands nearly erect. Having no power of flight, and not being able to run, the penguin may be overtaken with ease upon land; but once in the water, it distances its pursuers, swimming with the ease and rapidity of a fish. The Penguins are exclusively inhabitants of the southern seas; but the Puffins (*Fratercula arctica*)

Puffin (*Fratercula arctica*).

and Auks of the northern seas approach them in their peculiar characters. The former, which come to Britain, have short wings, capable of sustaining them for a little while. Of the latter, only one species has wings adapted for flight; all the other species are fitted for aquatic progression. The Great Auk (*A. impennis*) is now entirely extinct, having been destroyed by man himself. The Puffin obtains its food by diving into the water from a height, and often captures three or

four sprats at once. The Guillemots (*Uria*), which are found in all parts of the north of Europe and in the Arctic Seas, resemble the auks in the form of their bodies, and in their general habits. The Razor-bill (*Alca torda*) also belongs to this family.

In the family *Colymbidæ* (Divers), the wings are remarkably short, and the feet placed so far behind the point of equilibrium of the body, that they are ill adapted for walking. The Northern Diver (*Colymbus glacialis*) is a familiar example. It is generally an inhabitant of the most northern parts of the Old and New World; but on the approach of winter, it journeys southward, and is then occasionally found in Scotland. On the least alarm it dives under the water, rising perhaps a quarter of a mile from the spot where it disappeared. The Grebes (*Podiceps*) are more inland in their habits, living chiefly on the borders of lakes. The toes are separate, but each has a fin-like membrane along the side, presenting a considerable surface to the water. Of these, five species are found in our country, the most familiar being the Little Grebe (*P. minor*), and are largely killed for their feathers, which are used for making muffs, collars, &c. The Alcidæ and Colymbidæ are included by Owen under one family, which he calls the *Brevipennatæ*), in which the wings are short, and the legs are placed far back, so as to render progression on land very difficult.

The family of the *Laridæ* (Gulls) have well-developed, powerful wings, the three anterior toes united by a membrane, and the hinder one free. They feed on the carcasses that float in the sea, or are cast upon its shores. Genus *Larus* (Gulls proper): The Common Gull (*L. vulgaris*) is about one foot and a half in length, and three feet in the expanse of its wings; above, it is of a bluish-gray colour, and white beneath. On the approach of stormy weather, it leaves the shore, and sails round and round in circles at a great elevation. Genus *Sterna* (Terns), or Sea-swallows, are so called from the resemblance they bear to the Land-swallow in their pointed wings and forked tail. Their food consists of molluscs and fish. The tern is often seen chasing a small gull, in order to force it to disgorge the fish it may have taken. As soon as the fish has been dropped, the tern descends like an arrow, and generally succeeds in catching it before it reaches the water. The Common Tern (*S. hirundo*), which is about fourteen inches in length, visits our shores in April, leaving in September. Genus *Lestris* (Skuas) are more powerful birds than the terns. The Common Skua (*L. parasiticus*) is about two feet in length, and its general colour is a reddish-brown. Their peculiar habitat in this country is the Shetland Isles, where they breed in communities on unfrequented heaths. When the breeding is over, they retire to the sea, and feed upon fish-offal and animal matter.

The *Procellaridæ* (Petrels) differ from the Gulls in having no hinder toe, and having the upper mandible strongly hooked. The name Petrel (a diminutive of Peter) is given to these birds from their habit of walking on the waves. The common one (*P. pelagica*), called by mariners 'Mother Carey's Chickens,' is found in most seas. When it seeks shelter upon vessels, it is generally supposed as indicative of storms and shipwrecks. The largest member of the group is the gigantic Albatross (*Diomedea exulans*), which often measures fifteen feet across the wings. Its flight is very powerful, and it is often found at enormous distances from land in the northern and southern oceans. It is very voracious, and is said to destroy great numbers of flying-fish when they are forced to seek refuge in the air.

Owen included the two former groups under his family of *Longipennatæ*, which are characterised by their well-developed wings, by their pointed, sometimes hooked bill, and by their hinder toe never being united to the anterior toes by a membrane.

The *Pelicanidæ* (Pelicans) have the hinder toe directed inwards, and united to the innermost of the anterior toes by a membrane. The European Pelican is about as large as a swan, and altogether white. Attached to its long slender bill is

Pelican (*Pelecanus onocrotalus*).

a large neck-pouch, in which the fish are stored when captured. Nearly allied to the pelicans is the genus *Phalacrocorax* (Cormorants), in which the lower mandible is not furnished with a pouch, but the throat is capable of considerable dilatation. The Black Cormorant (*P. carbo*) is about the size of a goose, and is of a bronze-black colour. It is common on our shores, and is proverbial for its voracity. The Fishing Cormorant (*P. sinensis*) is an inhabitant of China, and is regularly trained and employed in fishing. Genus *Sula* (Gannet, or Solan Goose): These birds take their prey by hovering in the air at some little distance above the surface, and then dropping down upon any fish that they may see rising within their reach. They haunt the cliffs of solitary islands, for the purpose of bringing forth their young. The Bass Rock in the Firth of Forth, and Ailsa in the Firth of Clyde, are noted habitations of the Solan. It is eatable, but forms rather a coarse dish for most palates. The Frigate Bird (*Trachypetes aquilas*), which is distinguished by the immense length and power of its wing, and is often found far from land, and the Darter (*Plotus*), also belong to this group. The *Pelicanidæ* are called by Owen the *Totipalmatæ*, because they have the hinder toe directed inwards, and united to the innermost of the anterior toes by a membrane.

Family *Anatidæ* (Ducks) have the bill flattened in form, and covered with a soft membrane. The edges of the bill are furnished with a series of transverse plates, forming a kind of strainer for gathering food in a watery element. Of the genus *Cygnus* (Swan), the most remarkable wild species is the Hooper or Whistling Swan (*C. ferus*) of the Arctic Seas, which migrates southwards in flocks, under a leader, and ranged in the form of the letter

V, when their loud notes may occasionally be heard. The Tame Swan (*C. olor*) is a most elegant bird, and a beautiful ornament to our lakes and rivers. Swans are remarkable for their longevity. Genus *Anser* (Goose) presents several wild and migratory species. They all live on vegetable substances, and are useful as food. The *Canada Goose*, going northward every summer, is of great use to the Hudson's Bay residents, who kill and preserve great quantities for their winter provision. Our own tame goose is supposed to be derived from the Gray Lag Goose (*A. ferus*), once very abundant in the fenny districts of Lincoln. Genus *Anas* (Duck) includes many species, as the Velvet Duck, Eider Duck, Shoveller, and Shelldrake, all of them wild animals, frequenting pools and lakes remote from human haunts. The Mallard or Wild Duck (*A. Boschas*) is the parent of all the common ducks. The Common Duck, when searching for food amongst mud and turbid waters, is assisted by the sensitive skin of its bill, which enables it to feel for objects which it may devour. Another well-known species is the Eider Duck (*Somateria mollissima*) of the arctic portions

Common Eider Duck (*Somateria mollissima*).

of Europe and America, whose down is used for making quilts and similar articles.

The family of the *Phœnicopteridæ* (Flamingoes), from having the three anterior toes webbed, are entitled to be placed amongst the Natatores. They inhabit the marshes of hot climates. The Common Flamingo (*P. ruber*) is about four feet in height. It is purple red on the back, and has rose-coloured wings. The fleshy tongue was used by the Romans during the Empire as a great delicacy. The extreme length of their legs incapacitates them from sitting on their nests in the usual manner, so that they have to place themselves astride of them during the act of incubation.

Flamingo (*Phœnicopterus ruber*).

By Owen the last two families are called *Lamellirostres*, from the character of the bill, described under the *Anatidæ*.

Grallatores.

ORDER 2. *Grallatores* (Waders or Stilt-birds).—This order derives the name from their habits and conformation. Their bodies are raised upon long legs, like stilts. This elongation is mainly due to the elongation of the tarso-metatarsus. Their legs are unfeathered from the lower end of the tibia downward. They frequent the banks of rivers, lakes, marshes, and the shores of estuaries; and whilst resting with their feet on the land, derive their nourishment chiefly from the water; some feeding upon small fishes and reptiles, worms and aquatic mollusca; whilst others are more terrestrial in their habits and mode of feeding. The more aquatic species have a web to their toes. Their wings are long, and suited for flight. During flight, they stretch out their long legs behind, to counterbalance their long necks; and the tail is always extremely short, its function as a rudder being transferred to the legs. They mostly construct their nests on the ground, and the young are able to run about as soon as hatched, except in those species which live in pairs.

Family *Gruidæ* (Cranes) are elegant, large, and stately birds, with the bill strong and sharp-edged. The legs are long and slender. The Crane (*Grus cinerea*) is chiefly remarkable for its migrations, and it is described as a beautiful sight to see thousands of them passing over the Mediterranean in marshalled order, in groups of twenty to sixty, and each group headed by one of the larger birds. It is with reference to the migrations of these birds that Jeremiah (viii. 7) says: 'Yea, the stork in the heaven knoweth her appointed times.' Its length is nearly five feet, and its weight about ten pounds.

Family *Ardeidæ* (Herons): The Common Gray or Crested Heron (*Ardea cinerea*) is well

Common Heron (*Ardea cinerea*).

known in Britain. It passes the winter in the north of Africa, migrating thither in autumn,

and returning northward in spring. It is about three feet in length; its colour is of an ash gray, with a bluish tinge; and its head is ornamented with a crest. The Bittern, or Mire Drum (*Botaurus stellaris*), was once well known in Britain, but is becoming rare, as waste lands are reclaimed. It is the emblem of desolation, and as such is spoken of by the prophet in his denunciation against Babylon: 'I will also make it a possession for the bittern, and pools of water: and I will sweep it with the besom of destruction, saith the Lord of hosts.' The booming of the bittern is peculiarly dismal; and from this circumstance, and the lonely marshes it inhabited, it was the unconscious hero of many a ghost story in the superstitions that are past.

Of the Ibises (*Tantalinæ*), the most noted is the *Ibis religiosa*, which was held in great veneration in ancient Egypt, being often embalmed with their mummies, or figured on their monuments.

The *Ciconinæ* (Storks) have the bill strong and compressed. They are all large birds and feed upon reptiles and other small animals. They migrate in summer from Africa over a wide range of temperate latitudes. The Stork (*Ciconia alba*) stands about four feet high. In Holland, they prepare false chimneys on their houses, that the stork may build in them, each returning regularly to its own nest every year.

The Spoonbills (*Plataleadæ*) are large birds like the storks, but their bill is flattened in a broad spoon-like plate.

The family *Scolopacidæ* (Snipes) include the Snipe, Woodcock, &c. Their bill is long, slender, and cylindrical, and is used for searching in the mud for worms and insects. The Woodcock is well known in Britain, and is much esteemed for the exquisite flavour of its flesh. The Common Snipe (*Scolopax gallinago*) is one of the most common visitors of the British Isles. It chooses swampy parts of meadows; and insects, worms, &c. constitute its food. The Curlew (*Numenius arquata*), whose name is derived from its peculiar cry, also belongs to the family. The Sandpipers (*Tringidæ*), the Ruffs, and Avocat need no particular notice.

Curlew (*Numenius arquata*).

The Family *Rallidæ* (Rails), in which the bill is sharp, compressed, and wedge-shaped, includes several genera. *Gallinula* (Water-hen) is common throughout Europe. It frequents ponds and quiet water-courses. It is of a deep olive-brown colour above, and slaty gray below, with a frontal shield of bright red. The Coot (*Fulica atra*) is another well-known example of the Rails; the commonest species is the *Crex pratensis* (Land-rail, or Corn-crake), which is a regular summer visitor in the British Isles. It is of a reddish-brown colour, and conceals itself amongst grass and young corn, where it utters its peculiar cry. The Common Rail (*Rallus aquaticus*) remains in this country all the year round. In the Jacana, which inhabits Brazil, the feet are exceedingly long and slender, thus enabling it to run on the leaves of aquatic plants.

The *Charadriidæ*, or Plover tribe, are less aquatic than most of the other families. Their legs are short, and the hind toe is either absent, or so short as not to reach the ground. They congregate in flocks, on sandy and unsheltered shores, or on exposed commons, and run with great swiftness. The bill is of considerable strength, to enable them to penetrate the ground in search of worms. Several species of plovers exist in Britain, such as the *Charadrius pluvialis* or Golden Plover; the *C. morinellus*, or Dotterel; and the *C. hiaticula*, or Ring Plover. Some frequent the sea-coast, and others the upland moors. The Lapwings (*Vanellus cristatus*) are nearly allied to the plovers, and, like them, are migratory; they are peculiar to the Eastern hemisphere. They are very noisy birds, and defend themselves bravely against birds of prey. They derive their name from the stratagem by which they lure away intruders from their nests; they drop their wings in flight, appearing as if wounded, and thus induce their pursuers to follow them to a considerable distance. They are abundant in England, and are easily known by their wild and plaintive cry of 'peewit.'

The Oyster-catcher (*Hæmatopus ostralegus*) has a long, straight, wedge-shaped beak, which is strong enough to enable it to force open the bivalves upon which it feeds. The Turnstones (*Strepsilas*) derive their name from the habit they have of turning over the stones along the water's edge, in order to obtain the insects and small crustacea which are found beneath them.

Connecting the Grallatores with Rasores are the Bustards (*Otidæ*), in which the legs are long, and the toes are furnished with stout claws. Their wings are large, and their flight is easy. They are entirely confined to the Old World. The Great Bustard (*Otis tarda*), which is the largest of European birds, is one of the noblest of native British birds, and one of the finest kinds of game.

Order Cursores, or Runners.

ORDER 3. *Cursores.*—In this group, the wings are quite rudimentary, and the animals included under it are destitute of the power of flight. To compensate for this, they have remarkably strong limbs for running over the plains which they inhabit. Hence their name as an order. Their feathers present some resemblance to hairs.

The Ostrich (*Struthio camelus*) is an inhabitant of the wide-spread plains of Africa and Arabia. It is incapable of flight, but is remarkable for its swiftness of foot, being able to outstrip the fleetest horse. The legs are very strong, and terminated by two toes. It is from seven to eight feet in height.

The Rhea (American Ostrich) inhabits the plains of South America. It is smaller than the

ostrich. The head is feathered, and the feet have three toes each.

Ostrich (*Struthio camelus*).

The Emeu (*Dromaius Novæ Hollandiæ*) is confined to the Australian continent, and attains the height of from five to seven feet.

The Cassowary (*Casuarius galeatus*) is a native of Molucca and New Guinea. The head, which is naked, is surmounted by a horny crest. Its height is about five feet.

The *Apteryx* is confined to New Zealand. Its rudimentary wings are concealed beneath the

Apteryx (*Apteryx Australis*).

general plumage, and each is terminated by a short claw. The beak is long, slender, and slightly curved, and the nostrils are placed at the extremity of the upper mandible. It is nocturnal in its habits, and feeds upon insects and worms. It stands about two feet in height. The fossil remains of some gigantic wingless birds have been found in New Zealand, and have been referred to the genera *Dinornis*, *Palapteryx*, and *Aptornis*. The shin-bone of the *D. giganteus* measured about three feet in length, and the bird itself must have been about ten feet in height.

Rasores, or Scratchers.

ORDER 4. *Rasores* (Scratchers)—nearly corresponding with the *Gallinaceæ*, or Poultry tribes—are land-birds of bulky bodies, generally grain-feeders, gregarious in their habits, and readily domesticable. Their flesh is savoury and wholesome, and their fecundity great. The upper mandible is vaulted, and the nostrils are pierced in a membranous scale at its base. A cartilaginous scale covers the nostril. Their legs are thick and strong, with four toes, each of which is terminated by a strong short claw suited for scratching, hence their name as an order. The heads of many of the males are ornamented with elegant crests. Almost all of them have a large crop, and an extremely muscular gizzard. In general, they construct their nests on the ground. Each male usually associates with many females; he taking no part in constructing the nest or rearing the young, and these are generally numerous, and able to run about and provide for themselves the moment they quit the shell. The young of Pigeons, however, are brought forth in a comparatively helpless condition.

They are divided into two sub-orders—1. The *Gallinacei* or *Clamatores*, the latter name being derived from the character of their cry, including the *Phasianidæ* and *Tetraonidæ*. 2. The *Columbacei* or *Gemitores*, including the Doves and Pigeons.

The *Phasianidæ* (Pheasant or Fowl Family) are distinguished by the shortness of their hind-toe, the presence of spurs on the legs, and the beautiful development of the tail. Excluding the turkey, they are birds of the Old World. The Pheasant (*Phasianus*) derives its name from the Phasis, a river of Colchis, in Asia Minor, from which district it was first introduced into Europe. The Argus Pheasant (*Argus giganteus*), inhabiting

Argus Pheasant (*Argus giganteus*).

Sumatra, has large wings covered with eye-like spots, which give this bird a remarkable appearance. The Peacock (*Pavo cristatus*) is a native of the forests of India. Alexander the Great found it flying in great numbers in India, and introduced it into Europe. Its beautiful train has made this bird a favourite in the ornamental grounds of English country mansions. The Common Fowl (*Gallus domesticus*) are supposed to have originated in the Indian Archipelago, and to have been introduced at a still earlier period into Europe. Their usefulness and general habits are too well known to require description. The Turkeys (*Meleagrinæ*) are the only representatives of this group in the New World, whence they were brought by the early discoverers, and are now quite naturalised in Europe. A more splendid species than the common one has been subsequently discovered in the Bay of Honduras. The Guinea-fowl (*Numida*) is originally a native of

Africa, where it lives in large flocks in the neighbourhood of marshes. The *Megapodidæ*, or Jungle-fowl of Australia, from the size of the feet, may be mentioned along with this group. They are about the size of a turkey, are adorned with a crest, and have strong rasorial claws. Mr Gould says they do not incubate, but deposit their eggs in mounds of mould and vegetable matter; and by the natural heat engendered in these, the eggs are hatched.

The *Tetraonidæ* (Partridge or Grouse tribe) are all of them wild birds, inhabiting uncultivated grounds in the colder climates of Europe, Asia, and North America. They are distinguished by a short hind-toe, a short tail, and comparatively dull plumage. The Red Grouse (*Lagopus Scoticus*), Blackcock (*Tetrao tetrix*), and Ptarmigan (*Lagopus vulgaris*), abound in the Highlands of Scotland; and as the objects of a favourite amusement, give a value to much ground which would otherwise be nearly useless. They feed chiefly on the seeds of wild plants. The largest species of grouse is the Capercailzie, or Cock of the Woods (*Tetrao urogallus*), once abundant in Scotland, and still so in Norway. It feeds on pine-shoots, and grows to the size of a turkey. Nearly all the grouse have the toes and legs more or less covered with soft feathers—a character which disappears in the Partridges, an extensive group, scattered in nearly all parts of the Old World, but unknown in the New. Two species of Partridges are found in Britain—the *Perdrix cinerea*, or Common Partridge, and the *P. rubra*, or Red Partridge. In the Quails (*Coturnix*), we have the miniature resemblance of partridges, but the tail is so short as to be nearly imperceptible.

The family of the *Columbidæ* contains a large number of elegant and lovely birds. They are furnished with strong wings, and are more capable of flight than the other families of the Rasores. Their feet also are more slender, and well adapted for perching. The crop has a *double* dilatation, which expands on each side of the gullet; and the young are fed with grain disgorged from this receptacle by the parent, and impregnated with a secretion which it forms. These birds live invariably in pairs; they nestle in trees or in the holes of rocks, and lay but few eggs, though they breed often. This family includes the whole of the well-known tribe of Pigeons and Doves. The Common Dovecot-pigeon is derived from the Rock-pigeon (*Columba livia*), which naturally breeds principally among the sea-cliffs, and but sparingly inland. But the Ringed-pigeon (*C. palumbus*) is of a different stock; and though it chiefly frequents the districts cultivated by man, it resists his nearer approach. The Carrier-pigeon is not a distinct species, but only a variety of the common one which has undergone a particular training. The Ground Pigeons approach the *Gallinacei* somewhat in their characters. The Crowned Pigeon (*Goura coronata*) of the Indian Archipelago is nearly as large as a turkey. It is proper to mention an extinct species of fowl nearly allied to the pigeon tribe. The Dodo (*Didus ineptus*) existed in the Mauritius till the time of Charles II.; and we only know it now from the descriptions of voyagers, and certain fragments which have happened to be preserved. It was a bird about the size of a swan, with imperfect wings, utterly useless for flight, and only a small bunch of feathers in the usual situation of the tail; a large,

Dodo (*Didus ineptus*).

strong, curved beak; and legs and feet like those of a turkey.

Scansores.

ORDER 5. *Scansores*, or Climbing-birds, are distinguished at once by the structure of their feet. The foot has four toes, two of which are directed forwards and two backwards, so that the birds are specially suited for climbing. They are not good walkers or fliers, and build their nest carelessly; indeed, some of them build no nest, but deposit their eggs in the nests of other birds. They feed on insects and fruit. They are all more or less arboreal.

The Cuckoos (*Cuculidæ*): The Common Cuckoo (*Cuculus canorus*) derives its name from its peculiar cry. It is a migratory bird, arriving in this country about the end of April. It is chiefly

Common Cuckoo (*Cuculus canorus*).

remarkable in that it builds no nest of its own, nor does it hatch its own eggs, but deposits them in the nests of other birds, such as the hedge sparrow, by which they are reared. It deposits but one egg in each nest. The bird is about the size of a pigeon, and of an ash-gray colour.

Family *Picidæ* (Woodpeckers): They are well fitted for climbing trees, and are furnished with a long extensible tongue, covered with a viscid secretion, which they insert into the chinks of timber in search of insects. They make use of their pointed, stiff tail-feathers to assist them in maintaining their position. The Green Woodpecker (*Picinus viridis*), the Greater Spotted Woodpecker (*Dryobates major*), and the Lesser Spotted Woodpecker (*D. minor*), are constantly

resident in Britain. The Wryneck (*Yunx torquilla*) belongs to this family. In England it is called the Cuckoo's Mate, because its arrival and departure coincide pretty nearly with those of the cuckoo.

The *Psittacidæ* (Parrots) are a very extensive family, diffused over the torrid zone, and scarcely known beyond it. Their beak, which they use to assist them in climbing, is stout and large, the upper mandible being longer and larger than the lower, and hooked at its extremity. Their tongue is soft and fleshy. Their feet are specially suited for grasping and climbing. They live for the most part upon succulent fruits. Their larynx or organ of voice is very complicated, so that they can imitate the human voice as well as other sounds. They are nearly all adorned with gorgeous colours, and have been divided into several groups. The True Parrots (*Psittacinæ*) have square tails and no crests, and are found in the hot parts both of the Old and New World. The Cockatoos (*Cacatuinæ*) are also square-tailed, but have crests upon their heads. The white ones inhabit the Indian Archipelago and Australia. The Paroquets (*Pezoposinæ*) have a long-pointed tail, and chiefly inhabit Asia and Australia. The Macaws (*Arainæ*) are exclusively American, and

Macaw (*Ara ararauna*).

are superbly coloured. The Lories (*Lorinæ*) are oriental species, with dense soft plumage, and most gaudily coloured.

The Toucans (*Ramphastidæ*) have bills of enormous size, but the mandibles are to a great extent hollowed out and filled with air. They live upon fruits, and are confined to the warm regions of America. They are in general black, with lively colours on the throat and breast.

Insessores.

ORDER 5. The *Insessores*, or Passerine Birds (Perching-birds)—comprehends an immense number of species, whose characters seem principally negative; for it embraces those birds which are neither swimmers, waders, climbers, rapacious, nor gallinaceous. They have short and slender legs, with three toes before, and one behind. As a rule, the females are smaller, less brilliant in plumage, and less melodious than the males. They are, generally speaking, mixed feeders. They live in pairs, and their power of flight is considerable, and they display great art in the construction of their nests. Many of them are distinguished by their powers of singing. The sub-orders are founded on the form of the beak.

Sub-order 1. *Conirostres*—in which the beak is strong and conical, being broad at the base and tapering towards the apex. They are omnivorous, though a few are graminivorous. The order includes several families.

Family *Corvidæ:* The Common Crows are the most characteristic examples, and have long, strong, and compressed beaks. These animals are constructed for powerful flight, as well as for walking on the ground. They feed indiscriminately on animals or vegetables. They are bold, but wary, live in common societies, and possess great courage. Under the general term Crow are included the Raven (*Corvus corax*), which is the largest of European perching-birds; the Carrion Crow (*C. corone*), which is so destructive to eggs and young game; the Rook (*C. frugilegus*), which chiefly feeds upon grubs; the Hooded Crow (*C. cornix*), which feeds upon molluscs, &c. upon the sea-shore; and the Jackdaw (*C. monedula*), which lives in deserted buildings, but is troublesome on account of its propensity to secrete any small article of value that comes in its way. The Magpies (*Pica caudata*) and Jays (*Garrulus*) are nearly allied to the Crows. The Chough (*Frigilus graculus*) is closely allied to the Crows, but differs from them in having the bill notched at the top. The *Paradiseidæ* (Birds of Paradise) must be classed along with this family, although

Bird of Paradise (*Paradisea apoda*)—male.

they differ considerably from the ordinary *Corvidæ*. They are confined to New Guinea and the neighbouring islands. They feed upon insects and soft fruits, and are captured for their plumage, the extraordinary development of which is well known. The brilliant plumage is confined to the male.

The natives who captured them cut off their legs, so that, for a long time, it was supposed they were destitute of these appendages.

The family of the Starlings (*Sturnidæ*) closely resemble the crows, though they are weaker birds. The only species resident in Europe is the Common Starling (*Sturnus vulgaris*). It includes a number of curious birds, among them the *Icterinæ*, or Hang-nests of South America, which build long purse-like nests, suspended from the slender branches of lofty trees. It also includes the singular Bower-birds of Australia, which construct an elaborate bower, which serves as a sort of playing-ground, and where the birds make love to each other.

The *Fringillidæ* (Finches) are the smallest of this group of perching-birds, and are known by the shortness and strength of their conical bills. The Chaffinches (*Fringilla cœlebs*), Linnets (*Linota cannabina*), Goldfinches (*C. elegans*), Bullfinches (*Pyrrhula vulgaris*), Buntings (*Emberiza*), Sparrows (*Passer domesticus*), and Larks (*Alaudinæ*), all belong to this family. The Canary (*Carduelis canaria*) was originally imported from the Canary Islands. The Weaver-birds (*Ploceinæ*) of tropical climates construct remarkable nests of blades of grass interwoven together.

The *Buceridæ* (Hornbills) are confined to the Old World. They have a huge excrescence on the upper mandible, which is rendered light by the presence of spaces filled with air.

The *Loxiadæ* (Crossbills) are distinguished by a strong curvature of the mandibles, causing their tips to pass each other—a peculiarity which gives them a great advantage in extracting their favourite food, the seeds of the pine-cones.

Sub-order 2. *Dentirostres*—have a notch in the lower margin of the upper mandible near the tip. Although their food consists principally of insects, some of them are carnivorous.

The Shrikes (*Laniidæ—lanius*, a butcher) are highly predaceous, and they kill their prey, which consists of small birds, mice, &c. by repeated blows of the bill on the head. They are commonly called Butcher-birds.

The Fly-catchers, or *Muscicapidæ* (*musca*, a fly, and *capio*, I take), have a depressed beak, armed with bristles at the base. They are migratory, as they must be to obtain their prey. Two species are found in Britain, the Spotted Fly-catcher (*M. griseola*), and the Pied Fly-catcher (*M. luctuosa*).

Of the Thrushes (*Merulidæ*), the Blackbirds (*Turdus merula*) and the Fieldfares (*T. pilaris*) are well-known examples. Of the Thrushes, the best known are the Song-thrush or Mavis (*T. musicus*), the Ring-thrush (*T. torquatus*), and the Redwing (*T. iliacus*), all of which are found in Britain. The Mocking-birds (*Mimus polyglottus*), which are restricted to America, are remarkable for the singular gift of imitating the cries of many other birds. The Orioles are migratory birds, which frequent Southern Europe, where they build their curious hanging nests. The Dipper, or Water Ousel (*Cnidus aquaticus*), also belongs to this group.

The Warblers (*Sylviadæ*) are the most musical of European birds, including the Wagtails (*Motacilla*), Titmice (*Parniæ*), Hedge-sparrows (*Accentor*), Redbreasts (*Erythacus*), &c. The Nightingale (*Philomela luscinia*) is a migratory bird, which visits England in April, and leaves it in August. It builds on trees, and does not sing till the young

Nightingale (*Philomela luscinia*).

ones are hatched. The notes which it then gives forth have in all ages been a theme of admiration.

Sub-order 3. *Tenuirostres* (Slender-billed birds)—are known by possessing a long slender beak, tapering to a point. Their toes are long and slender. Most of them live on insects, though others subsist on the juices of flowers.

The *Meliphagidæ* (Honey-suckers) are chiefly confined to Australia. Their tongue is terminated by a bunch of fine filaments, and the hind-toe is so strong that it serves as a support to the bird while feeding.

The *Trochilidæ* (Humming-birds), so celebrated for the metallic lustre of their plumage, are pre-eminently South American. They have within their long slender beak a bifid tongue, suited for catching insects within the corollas of flowers, or of sucking the juices of the flowers themselves. When hovering over flowers, these birds balance themselves in the air by a rapid motion of the wings, and it is by this movement that the *humming* sound is produced from which they take their name. Some of them do not weigh more than twenty grains when alive. More than 170 species are known.

The family of the *Certhidæ* (Creepers) includes the Nuthatch (*Sitta Europæa*), the Brown Creeper (*Certhia familiar*), and the familiar little Wrens (*Troglodytes*). It also includes the singular Lyre-bird of Australia (*Menura superba*), so called from the peculiar arrangement of its tail-feathers.

The Sun-birds (*Promeropidæ*) represent the humming-birds in the Eastern continent. They are small birds, and the males have the most brilliant colours, rivalling those of the humming-birds, during the breeding season; but the garb of the female, and of the male at other parts of the year, is much more dull.

The Hoopoes (*Upupidæ*) are restricted to the Old World. The Common Hoopoe (*Upupa epops*) annually visits Europe in company with the Bee-eaters.

Sub-order 4. *Fissirostres* (Cleft-beaks)—have the beak deeply cleft, which gives a wide gape, and fits these birds for catching insects on the wing. The gape is usually furnished with bristles, which greatly facilitates the capture of their prey.

The family *Hirundinidæ* (Swallows) are well-known summer visitors of Britain. Their movements in flying are vivid and irregular. The feet

have three toes before and one behind, and all four are armed with strong claws, giving the animal the power of clinging to the faces of perpendicular rocks and buildings. The Martin (*Hirundo urbica*) builds its mud-nest in the sheltered angles of buildings.

The Swifts (*Clypselidæ*) differ from all other birds in having all the four toes directed forwards. The Common Swift (*C. opus*) possesses more enduring powers of flight than the swallow, which is often seen on its long journeys to fall wearied into the sea. The nest of a species of swallow (*Collocalia esculenta*), from the Indian Archipelago, is used by the Chinese for making soup. The nests are composed of a mucilaginous substance, which is secreted by greatly developed salivary glands, and is more or less mixed with grass and other similar materials.

The Goat-suckers (*Caprimulgidæ*) have large eyes, a soft plumage, and fly in the dusk, and

Common Goatsucker (*Caprimulgus Europæus*).

feed on insects, which they seize on the wing. They derive their name from the absurd belief of the ancients, that they injured the teats of goats in their attempts to suck them. Only one species (*C. Europæus*) is found in Britain. It arrives from Africa in May, and takes its departure in September.

The Bee-eaters (*Meropidæ*) are so named because they feed on bees, which they pursue much in the manner of swallows. In spring, they cross the Mediterranean from Africa to the south of Europe, where they breed.

The Kingfishers (*Alcedinidæ*) are generally natives of warm climates. The Common Kingfisher (*Alcedo ispida*) lives upon small fish, and may be seen perching on the stump of a tree which overhangs a stream, watching the minnows, on which it darts with unerring aim. It then returns to its perch, beats its victim to death, and swallows it. The Laughing Jackass (*Dalas gigas*) of Australia, whose song resembles a lengthened hysterical laugh, belongs to this family.

Raptores, or Birds of Prey.

ORDER 6. The *Raptores*—are designed to feed on the weaker animals of their own and other tribes. Their bill is strong, hooked, and sharp pointed. Their talons are sharp, and more or less retractile. They are very muscular birds, and strong on the wing. The female is larger than the male. They form pairs, live solitarily, and do not breed large families. This order comprises two sections.

Section 1. *Nocturnal Raptores*—which hunt by night, and have the eyes directed forward. It includes the single family *Strigidæ* (Owls). They hunt their prey by night, and their flight is noise-

1. Great Eagle or Owl (*Bubo maximus*); 2. Long-eared Owl (*Otus vulgaris*); 3. White or Barn Owl (*Strix flammea*); 4. Foot of Snowy Owl (*Strix nyctea*).

less, as their feathers are very loose and soft. Owls in ancient times were regarded as emblems of wisdom. This family contains only a single genus—*Strix*, which is divided into two sections—Horned or Eared Owls, which have a tuft of long feathers on each side of the forehead; including the Long-eared Owl (*Otus vulgaris*), and the Short-eared Owl (*O. brachyotus*), which are British species; and the Horned Owl (*Bubo maximus*), which is common in the forests of Europe; and the Smooth-headed Owls, which are destitute of these appendages, represented by the Barn Owl (*Strix flammea*), which subsists upon mice and small birds, which it swallows whole. The bones and other indigestible parts are afterwards disgorged in small pellets.

Section 2. *Diurnal Raptores*—in which the eyes are placed laterally, and smaller than in the former group, and the plumage is not soft.

The *Falconidæ* or *Accipitrinæ* (Hawks, Falcons, Eagles) have the upper mandible notched, and their claws strong and retractile. The head and neck are always clothed with feathers. Their flight is graceful, and their courage very great. The Falcons proper (*Falconidæ*) are specially adapted to pursue and bring down their prey on the wing. The Eagles (*Aquilinæ*) are the largest and most powerful of the whole group, and pursue and destroy quadrupeds as well as birds. Their legs are feathered quite down to the toes. They build their nests in lofty and secluded situations, among mountains and precipices, and resist with great courage any attack upon their young. The Hawks, Harriers (*Circinæ*), and Kites (*Milvinæ*) also belong to the family. The Kites have the power of hovering balanced on their wings for a longer time than any of the known birds. The Osprey (*Pandion Haliaëtus*) is aquatic in its habits, living upon the sea-shore, and subsisting principally on fish. It is at once distinguished by the roughness of the under surface of the foot, which assists it in holding its slippery prey.

In the family *Vulturidæ* (Vultures) the eyes are destitute of an eyebrow, and the head and neck are either naked or covered with a short down. Their food consists chiefly of dead carcasses and offal, with which they often gorge themselves to such an extent that they are reduced to stupidity. In hot climates, they are of great service in consuming putrefying bodies, which would otherwise infect the air. No sooner is an animal dead, than its carcass is surrounded by numbers of these birds, which suddenly appear, coming from all quarters, in situations where immediately before not one had been seen. The Bearded Vulture (*Gypaëtus barbatus*), or Lämmergeyer of the Swiss

Lämmergeyer (*Gypaëtus barbatus*).

and German Alps, the largest of the European birds of prey, measures nine or ten feet in the

Secretary Bird (*Serpentarius secretarius*).

expanse of its wings. It feeds upon goats, sheep, &c. which it kills by precipitating them down steep declivities. The Griffon, or Golden Vulture (*V. cinereus*), is also common in the Alps. These species differ from the true Vultures in having the head and neck feathered.

The Condor (*Sarcoramphus*), the king of the Vulture tribe, is peculiar to the Andes. The extent of its wings when expanded is from ten to twelve feet. Borne on these wide-spread pinions, the Condor ascends higher than any other bird, being sometimes found at an elevation of 10,000 or 15,000 feet above the level of the ocean. The Common Secretary Vulture (*Serpentarius secretarius*) of the Cape of Good Hope and the Philippine Islands, derives its name of Secretary from the feathers at its ear presenting the appearance of a pen. Its neck and legs are much lengthened, and it subsists upon poisonous reptiles, hence its generic name. The *Neophron Percnopterus*, or Egyptian Vulture, which is common in the northern part of Africa, subsists entirely upon carrion.

ORDER 8. *Saururæ.*—This order includes only the extinct bird, the *Archæopteryx macrura*, the

Remains of *Archæopteryx* in Solenhofen Stone.

remains of which were found in the lithographic Solenhofen slate (Upper Oolite). It was about the size of a rook, and differed from all known birds in having twenty caudal vertebræ, each of which supported a pair of quill-feathers, and in having two free claws belonging to each wing.

CLASS V.—MAMMALIA, OR SUCK-GIVING ANIMALS.

The Mammalia are universally regarded as the highest group in the Animal Kingdom; because they possess the most complex organisation, adapted to perform the greatest number and variety of actions, and to execute these with the

greatest intelligence. They have a double circulation, and warm blood, and breathe by lungs; but the air-tubes terminate in the air-cells of the lung, and do *not* open on the surface of the lungs as in birds. The skull is articulated to the backbone by two occipital condyles, and the cavities of the thorax and abdomen are separated by a partition or diaphragm, which is not the case in birds. They produce their young alive, and nourish them by a special fluid, the milk, secreted by special glands—the mammary glands, hence the name of the class. Further, some part of the skin is provided with *hair* at some period or other of the animal's life.

Naturalists, in seeking to classify the Mammalia, have to look chiefly to those indications which the teeth, extremities, and other external characters furnish, regarding the general habits and dispositions of the several animals. Thus, keeping out of view minor distinctions, the possession of sharp fangs and claws is a clear mark of carnivorous habits; flat-topped teeth and hoofs, equally a proof of a gentle and herbivorous character. The flapper of the whale shews a fitness for progression in the sea; the development of a wing on the hand of the bat, a design that the animal should make its way through the air.

Teeth are present in most of the Mammalia, and their form, number, and mode of arrangement yield important characters in the classification of this class. In man and most mammals there are two distinct sets of teeth—one set which appears shortly after birth, and which are termed the *milk* or *deciduous* teeth, and a second set, which, after a few years, replaces them, termed the *permanent* teeth. There are four kinds of teeth (permanent set) met with in the jaw of a typical mammal, such as a dog. They are, the *incisors*, which are implanted in the pre-maxillary bones, and in the corresponding part of the lower jaw; the *canines*, or eye-teeth, those next to them in order backwards; the teeth which displace the deciduous molars or grinders are called *premolars;* and the most posterior teeth, which are not displaced, are the true *molars*, which are not represented in the deciduous set. For briefly expressing the number of teeth in any mammal, a *dental formula* is employed. The permanent teeth in man are represented by the formula:

$$\text{I.}\ \frac{2-2}{2-2},\ \text{C.}\ \frac{1-1}{1-1},\ \text{P.}\ \frac{2-2}{2-2},\ \text{M.}\ \frac{3-3}{3-3} = 32;$$

where the letters stand for the four kinds of teeth enumerated above, and where the two terms in each nominator and in each denominator represent the number of each particular kind of tooth in each half of the upper and lower jaw respectively. All the teeth are implanted in distinct sockets in the lower jaw.

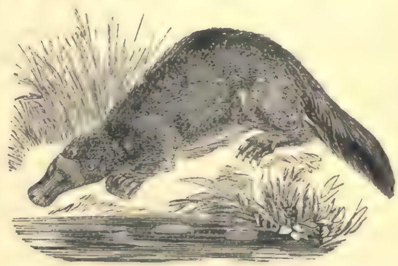
Owen classified this group according to the structure of their brains, and De Blainville founded his leading subdivisions upon the structure of the reproductive organs. The Mammalia are primarily divided into two sections:

Section I.

Implacentalia, including the following two orders, where there is no vascular connection (*placenta*) between the fœtus and the mother, and the young are brought forth in a very immature state of development.

ORDER 1. The *Monotremata* (*monos*, single, *trema*, an aperture)—so named because, as in birds, the excretory organs are united into one—are exclusively Australian, and are represented by two genera.

The Spiny Ant-eater (*Echidna*) is about the size of, and somewhat resembles a hedgehog, has a prolonged snout, and its back is armed with spines. It has no teeth, and its food consists of ants, which it entraps with its long adhesive tongue. It is represented by two species (*E. hystrix* and *E. setosa*). The *Ornithorhynchus* (*ornis*, a bird, and *rygchos*, a beak), or Duck Mole, is so called from its bird-like snout. There is only a single species, *O. paradoxus*. Its body is about the size of



Duck-billed Platypus (*Ornithorhynchus paradoxus*).

a small otter, and is covered with dense fur. The legs are short, and the feet have five toes each, armed with strong nails suited for burrowing. The toes are united by a web, so that the animal can swim. It has no teeth, and its skull bears a strong resemblance to that of a bird. It burrows in the banks of tranquil rivers, and obtains its food by the capture of small aquatic animals.

ORDER 2. *Marsupialia*, or Pouched Animals (*marsupium*, a pouch), derives its name from the remarkable provision which is made for the young after their immature birth. The skin of the parent is so disposed as to form a pouch into which the teats project, in which the immature young are placed after birth, where they remain attached to the teats until they acquire a degree of development comparable to that with which other animals are born. The angle of the lower jaw is always turned inwards.

The geographical range of this order is extremely peculiar. With the exception of the Opossums, which inhabit America, its species are at present almost confined to Australia and the neighbouring islands, where they constitute, with the Monotremata, almost the only mammiferous animals. They have been divided by Owen into families according to their predominating food.

(A.) *Rhizophaga*, or Root-eaters, as the Wombat, which exhibits a curious resemblance to the herbivorous Rodents in its dentition and in its alimentary canal. The Wombat (*Phascolomys fossor*) is about the size of a badger, by which name it is known to the colonists, and is a native of Tasmania. It is a sluggish and nocturnal animal, which burrows in the forests and low grounds, and feeds upon the tougher kind of vegetable substances.

(B.) *Poephaga*, or Grass-eaters, have long incisors, the canines generally wanting, and a complex intestinal canal like herbivorous mammalia. It includes the Kangaroos and the Kangaroo-rat, all of which are inhabitants of Australia and the neighbouring countries. The Kangaroos are remarkable for the enormous length of their hinder feet, whence their generic name, *Macropus* (long-footed), is derived. The hind-legs and tail are also very largely developed; whilst the fore-legs and feet are very small. From this great inequality in the size of the limbs, they advance on all-fours very slowly; but they can make immense leaps with the hind-legs, the tail probably assisting them. The dental formula is:

$$\text{I.}\ \frac{3-3}{1-1},\ \text{C.}\ \frac{0-0}{0-0},\ \text{P.}\ \frac{1-1}{1-1},\ \text{M.}\ \frac{4-4}{4-4} = 28.$$

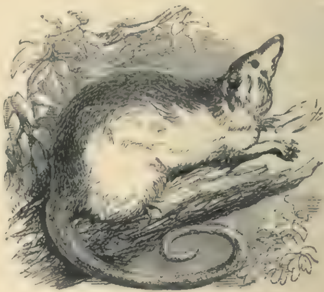
The young ones reside in the maternal pouch until they are able to graze for themselves. The

Great Kangaroo (*Macropus giganteus*).

largest species is sometimes six feet in height, having the bulk of a sheep, and weighing 140 pounds. Its flesh is used as food by the native Australians. The Kangaroo-rat (*Hypsi prynnus*) is a nocturnal animal about the size of a small rabbit. It has canines in the upper jaw.

(C.) *Carpophaga*, or Fruit-eaters, have large and long incisors in both jaws, the canines sometimes absent, and a complicated intestinal canal. They are peculiarly adapted to live among trees, on which they seek their food. The *Petaurus* (Flying Phalanger) of Australia possesses an extension of the skin on each side of the body, between the anterior and posterior limbs, by the help of which it is enabled to take extensive leaps from tree to tree. Like the flying squirrels, they have no true power of flight. It is a nocturnal animal, with a delicate fur. The Phalangers (*Phalangistidæ*) are so called because the second and third digits of the hind limb are joined together almost to their extremities. The Australian Opossum (*Phalangista vulpina*) is hunted for its flesh, which is considered a great delicacy. The *Pholascolarctos*, or 'Koala,' or native sloth' of New Holland, which is nocturnal in its habits, has the gait and carriage of a young bear, and passes its life upon trees.

(D.) *Entomophaga*, or Insect-eaters, have canine teeth in the jaws, and prey on the weaker classes of invertebrate animals. Some live on the ground; while others, such as the opossum, ascend trees in search of food. The Opossum tribe are extensively diffused over, and belong exclusively to, America. They have a long prehensile tail, and the thumb is opposable to the other digits.



Virginian Opossum (*Didelphys Virginiana*).

They are nocturnal animals of slow gait, and nestle upon trees, where they pursue birds, insects, &c. without rejecting fruit. The Virginian Opossum (*Didelphys Virginiana*) is about the size of a cat. The dental formula is:

$$\text{I.}\ \frac{5-5}{4-4},\ \text{C.}\ \frac{1-1}{1-1},\ \text{P.}\ \frac{3-3}{3-3},\ \text{M.}\ \frac{4-4}{4-4} = 50.$$

In some species of opossum, only the vestige of a pouch is present; in these cases, the female supports her young by entwining her tail with theirs. The Banded Ant-eater (*Myrmecobius fasciatus*), remarkable for its large number of molar teeth, and the Bandicoots (*Paramelidæ*) of Australia, also belong to this group.

(E.) *Sarcophaga*, or Flesh-eaters, fill the place held by the carnivora in other parts of the world. Their canines are long and pointed, and their molars are set with cusps, and their stomach is simple. The *Thylacinus* is about the size of a wolf, is a native of Tasmania, and is called the 'hyæna.' The *Dasyurus*, or 'native devil,' is also found in Tasmania, and though smaller than the former, it is very predaceous, destroying sheep, and even invading houses.

Section II.

Placentalia—where the young before birth are connected with the mother by a *placenta*, and are brought forth in a comparatively advanced stage of development. The placenta is 'a structure which is developed by the interlacement of the vessels of the offspring with those of the parent, and by means of which the former is enabled to receive nourishment, and to get rid of effete matters.' The brain also in this section is better developed than in the *Implacentalia*. It includes all the remaining orders of the Mammalia.

ORDER 3. *Edentata*—derive their name from the fact, that in all (with one exception) the incisor teeth are absent. The teeth are simple in structure, and have no roots. Their feet are furnished with long and powerful claws.

The family of the *Myrmecophagidæ*, or Ant-eaters, have a pointed muzzle, with a long, glutinous tongue, admirably adapted for catching burrowing insects, such as ants. The best known is the *M. jubata*, or great Ant-eater, which feeds upon ants. Its body is covered with hair, and its jaws are without teeth. They belong to South America. Nearly allied to this group is the Pangolin (*Manis*), or Scaly Ant-eater, which is confined to Asia and Africa. Its tongue resembles that of *M. jubata*, but its body is clothed with overlapping scales, which constitute a defensive armour when the animals roll themselves up into a ball, as they do when alarmed. Another family of the Armadillos (*Dasypodidæ*), are remarkable

Armadillo (*Dasypus sexcinctus*).

for the dense armour of hard scales arranged in tranverse rows with which they are covered. The molar teeth in *D. gigas* exceed ninety in number. They have short legs, and long and powerful claws suited for burrowing. A colossal extinct form, *Glyptodon*, has been found in South America. It had no bands in its armour, so that it was unable to roll itself up, as the Armadillos do. They feed chiefly on insects, and are confined to South America. The *Bradypodidæ*, or Sloths, have a round head and short face, and the body covered with hair. Their forearms are very long, and armed with long claws, by which the animal is enabled to suspend itself back downward from the trees on which it lives. While walking, and even in sleep, they retain this peculiar position.

Three-toed Sloth (*Bradypus trydactylus*).

They seldom leave a tree unless compelled through force or accident. They are exclusively South American. Fossil remains of two very large animals in this family have been discovered in America—the Megatherium, Megalonyx, and Mylodon—nearly equalling the elephant in size.

ORDER 4. *Cetacea* (Whales)—are in general bulky animals, with a fish-like form, and adapted for an aquatic life. The anterior extremities are fashioned into paddles or 'flippers,' for progression; the posterior pair are absent. The tail is a powerful, *horizontally* flattened organ (the tail of fishes being flattened vertically), which enables the animal to rise from the depths of the ocean to take a breath on the surface, or to dive suddenly below. Underneath the naked skin is a layer of fat or 'blubber,' forming at once an elastic padding, to enable the animal to resist the pressure of the sea at great depths, and a comfortable wrapping, to save its natural heat from escaping into the cold element amidst which it lives. Whales are captured principally for the oil which this blubber yields. Another feature of the whales is the situation of the nostrils terminating at the crown of the head, and forming the *spiracles* or 'blow-holes.' The phenomenon of 'blowing' is caused by the sudden condensation in a cold atmosphere of the watery vapour contained in the expired air.

The family of the *Balænidæ* (Whalebone), or Toothless Whales, which sometimes attain the length of 70 feet, are characterised by the total absence of teeth in the adult, although teeth which never cut the gum are present in the fœtus. Their place is supplied by a series of horny plates, arranged round the jaws, and forming simply a *strainer*. The animal, having taken in a huge mouthful of water, containing small animals, expels the water through this apparatus, leaving the prey behind, which is then swallowed. From this *baleen*, as it is called, is derived the article in common use under the name of *whalebone*. It gives a generic name to the group of animals possessing it. The Common Whale (*Balæna*

Greenland or Right Whale (*Balæna mysticetus*).

mysticetus) is an inhabitant of the Arctic Seas, and its capture is the subject of a great trade. The sailors transfix it with a harpoon, to which a line is attached, and when it rises exhausted to the surface, they kill it, and extract the blubber. The great danger of this business is from the tail of the whale, which is quite able to upset a boat, or even to cut it in two. The Rorqual (*Balænoptera*)

is another species, in the same seas, different chiefly in being longer, with a more slender body. Its whalebone is comparatively valueless.

The family of the *Physeteridæ* (Cachelot or Spermaceti Whales) are inhabitants of the Southern Ocean. They have teeth in the lower jaw, but have no baleen. The best known is the Spermaceti Whale (*Physeter macrocephalus*), from a cavity in the head of which the substance called spermaceti is obtained. They are distinguished by the bulk of their heads, in which a surprising quantity of fat is lodged.

The *Delphinidæ* are smaller animals, generally seen in droves, and are very active and lively in the water. They have teeth in both jaws. The Dolphin (*Delphinus*) and Porpoises (*Phocœna*) belong to this group. The latter are often seen on our shores, to which they come in pursuit of herrings. The Narwhal (*Monodon monoceros*), or Sea-unicorn of the Arctic Seas, has one of the upper incisor teeth developed to the length of six feet, forming a formidable weapon, which is spirally twisted, and grows throughout the life of the animal.

The *Sirenia*, or Sea-cows, correspond with the true whales in the important character of the absence of the posterior extremities, and for convenience may be placed in the same order. The Dugongs (*Halicore*) of the Indian Ocean—the Manatees (*Manatus*) of the Gulf of Mexico—belong to this group. They are herbivorous, living upon submarine plants. They are supposed, from the resemblance which their face and head, when seen above water, presents to the human lineaments, to have given rise to many of the stories regarding mermaids.

ORDER 5. *Ungulata*, or Hoofed Animals—includes the two old orders, *Pachydermata*, or thick-skinned animals, such as the rhinoceros and pigs; and the *Ruminantia*, such as sheep and goats. There is an exceedingly large number of genera and species, and they all present the following characters: All the four limbs are present, and are only useful for support and progression; hence they are destitute of clavicles. There are never more than *four* toes to each foot, and the part of the foot touching the ground is encased in a *hoof*. The molar teeth are broad crowned, and suited for grinding vegetable substances. This order is divided into two sections.

Section 1. *Perissodactyla*—in which the toes or hoofs are *odd* in number (one or three). The animals comprised under this section further agree in having the hind-foot odd-toed in all, and the fore-foot in all except the Tapirs. The thigh-bone has a third trochanter. If horns are present, they are placed in the middle line of the body, and have never a bony core. The stomach is simple, and the cæcum is capacious.

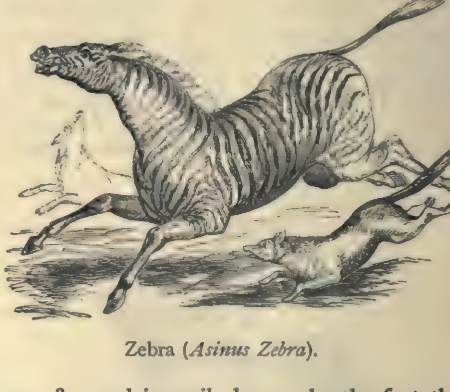
Family 1. *Rhinoceridæ*.—The Rhinoceros is a bulky animal, with a thick skin, which is generally thrown into folds. Its head is furnished with a horn, composed of agglutinated hairs placed in the middle line of the snout. Sometimes a second horn is present; if so, it is placed *behind* the first. They are ferocious, frequenting marshy places, and living on herbage and branches of trees. Several species are known in the tropical parts of the Old World. The best known are the Indian Rhinoceros (*R. Indicus*), and the African form (*R. bicornis*), which is found in the south of Africa. An extinct species, the Wool Rhinoceros (*R. tichorhinis*), formerly existed in England. Its bones are frequently found fossil in caves, such as

Rhinoceros (*Rhinoceros Indicus*).

Kirkdale cave in Yorkshire. The Hyrax, which is about the size of a rabbit, is nearly allied to the rhinoceros. It is found in Syria and Africa, and is supposed to be the 'cony' of Scripture.

Family 2. *Tapiridæ*.—In the Tapirs, the fore-foot has *four toes*, which are unsymmetrical, and the hind-foot has three, all encased in hoofs. The tapirs have a thick hairy skin, a short movable trunk, and a short tail. The Tapir of America (*T. Americanus*) is about the size of an ass, is brownish-black in colour, is strictly herbivorous, and is nocturnal in its habits. The fossil *Palæotherium*, from the gypsum quarries of Eocene age, near Paris, is an allied but larger species, but all the feet have three toes each.

Family 3. *Solidungula*, or *Equidæ*.—This family comprises the Horse, Ass, Zebra, Quagga,



Zebra (*Asinus Zebra*).

Onaga, &c. and is easily known by the fact that each foot has only a single perfect hoof. The dental formula is:

$$\text{I. } \frac{3-3}{3-3}, \text{ C. } \frac{1-1}{1-1}, \text{ P. } \frac{3-3}{3-3}, \text{ M. } \frac{3-3}{3-3} = 40.$$

In the males, canines exist in the upper jaw; but they are absent in the female. From the species of horse, *Equus caballus*, all the varieties of horses are descended. It is a native of Central Asia. The Ass (*Asinus*) and Horse are noted for

their usefulness to man as beasts of burden, docility and strength being combined in them in a remarkable manner.

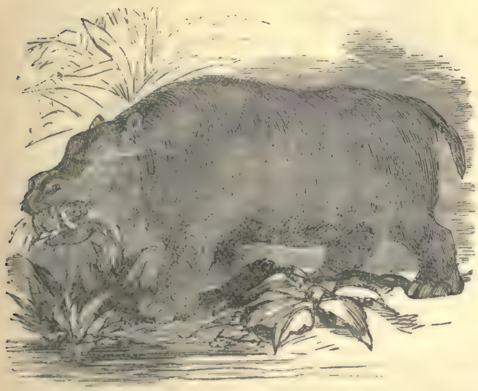
Section 2. *Artiodactyla*—in which the toes or hoofs are *even* in number (two or four). There is no third trochanter to the thigh-bone. When true horns are present, they are paired, and supported by a bony cover. The stomach is complex, and the cæcum is small.

Sub-section Omnivora.

Family 1. *Hippopotamidæ.*—This group contains but one genus, the *Hippopotamus*, or River-horse, &c. It is a massive and unwieldy animal, about 11 feet in length, with a thick skin, which is furnished with a few hairs. Its muzzle is blunt, and its head large. Three kinds of teeth are present in each jaw, the dental formula being :

$$\text{I. } \frac{2-2}{2-2} \ \text{C. } \frac{1-1}{1-1}, \text{M. } \frac{6-6}{6-6} = 36.$$

The canines are very large, and the crowns of its molar teeth are adapted for grinding roots and vegetable substances. The feet have four toes each. Only one species is known (*H. amphibius*), which is confined to Central and Southern Africa.



Hippopotamus (*Hippopotamus amphibius*).

Family 2. *Suida*, or Pig tribe, are characterised by their thick skin, and by the presence of only two functional toes to each foot, the other two toes being rudimentary, and placed some distance above the ground. There are three sorts of teeth in each jaw, and in the males the canines project forward as tusks. The snout is rounded, and resembles a truncated cone. Their food is principally vegetable. The domesticated pig is an omnivorous animal. The Wild Boar (*Sus scrofa*) is a ferocious animal, which abounds in some forests of Europe, and is probably the source from which our domestic breeds are derived. In the Babyroussa (*S. babyrussa*) of the Indian Archipelago, the upper canines are very long, and grow spirally upwards and backwards, and serve as offensive and defensive weapons. In South America this family is represented by the Peccaries (*Dicotyles*), which want the external toe on the hind-feet, of which the commonest species is the Collared Peccary (*D. torquatus*).

The fossil *Anoplotheria*, from the Eocene rocks, exhibited a transition between the *Suida* and the *Ruminantia*. They were slender of form, and the dental formula is :

$$\text{I. } \frac{3-3}{3-3}, \text{C. } \frac{1-1}{1-1}, \text{M. } \frac{7-7}{7-7} = 44.$$

Their peculiarity is that the molars come close to the canines, without leaving an interval, a mode of arrangement found nowhere amongst Mammalia except in man himself.

Sub-section Ruminantia.

Ruminantia, or Ruminant Animals, are the most natural and best determined group of the mammalian class. In a typical ruminant (ox, sheep), there are no incisor teeth in the upper jaw, their place being taken by a hardened pad of gum, against which the lower incisors impinge. In the upper jaw there are only six molars on each side, with double crescentic ridges of enamel, which aid in masticating, but no canines. There are eight incisors in the lower jaw, behind which is a space, and then come six molars on each side. The feet are each terminated by two toes and two hoofs, which present a flat surface to each other, appearing as though a single hoof had been cleft ; hence the names that have been applied to these animals of 'cloven-footed,' &c. There are also usually two vestiges of lateral toes placed at the back of the foot.

The name of the order intimates the singular faculty possessed by these animals of masticating their food a second time, or 'chewing the cud.' This faculty depends on the structure of their stomachs, which are four in number. The food, which is cropped by the incisor teeth, is swallowed almost without mastication, and is moistened in the first stomach or *paunch*. It then passes into the *reticulum*, or honey-comb bag, whose inner surface is divided by ridges into a number of hexagonal cells (hence the name), where, after being rolled into pellets or *cuds*, it is returned into the mouth, to be rechewed while the animal is at rest. It is then swallowed a second time, but this time it goes into the *omasum*, or 'many-plies,' so called because its lining membrane is thrown into folds resembling a book ; finally, it passes into the last cavity, or *ab-omasum*, and then into the intestine, which is of great length. Taken as a group, these animals are timid, and destitute of powerful means of defence against their foes. When feeding, they are liable to many alarms ; and if they were compelled to spend a considerable time in masticating their food before swallowing it, they would often have to leave their pasture before their wants are supplied. They convey a store of food into the first stomach, and then retiring to a secure place, they prepare it for digestion at their leisure.

The Ruminants are, of all animals, the most useful to man. They supply him with a large proportion of his animal food. Some serve him as beasts of burden ; others furnish him with their milk, their tallow, hair, leather, horns, and other useful products.

(A.) The *Camelidæ*, or Camel tribe, differ from the typical Ruminants in having two incisors in

the upper jaw, and canines in both jaws, the dental formula being:

$$\text{I.}\ \frac{1-1}{3-3},\ \text{C.}\ \frac{1-1}{1-1},\ \text{P.}\ \frac{3-3}{3-3},\ \text{M.}\ \frac{3-3}{3-3} = 36.$$

Their head is destitute of horns.

In the true Camels, which are peculiar to Asia and Africa, the two toes are united below by a kind of horny sole, almost to their points, which terminate in small hoofs; and there is a soft cushion beneath the foot, by which it bears upon the sandy surface over which it is formed to move. Two species are known—one called the Bactrian (*Camelus Bactrianus*), or Two-humped

Camel (*Camelus Bactrianus*).

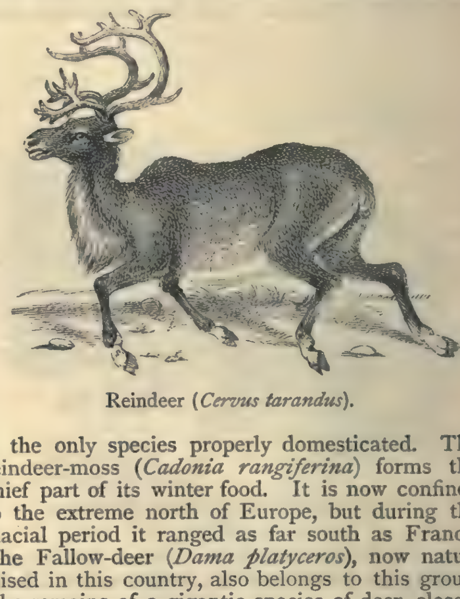
Camel, and the other the Arabian (*C. dromedarius*), or One-humped. Both are completely domesticated, and their utility as beasts of burden is universally known. The Two-humped Camel is the larger and stronger, being capable of sustaining a burden of above 1000 pounds, and is best adapted for rugged ground. The other is the most abstemious, and the best fitted for the sandy desert. The Dromedary is merely a lighter variety of it, possessed of greater fleetness and power of endurance. The flesh and milk of the camel serve as food, and the hair for the manufacture of cloth. Their humps, principally composed of fat, are provisions of superabundant nutriment, as they are noticed to diminish much in size on long journeys. By resting on their callosities, camels are enabled to repose on a scorching surface, and their stomachs are adapted to contain a supply of water sufficient for several days.

The place of the camels is taken in the New World by the Llama and Alpaca (*Auchenia*). They have no hump, nor is the sole of the foot provided with a pad. They are smaller than the camels, and are used as beasts of burden.

(B.) The *Moschidæ*, which includes the Musk Deer (*Moschus moschiferus*), are characterised by the absence of horns, and by the presence of canine teeth in both jaws, these teeth assuming, in the upper jaw of the male, the form of tusks. The male has a glandular sac in the abdomen, which secretes the well-known perfume musk, hence the name. They are elegant and nimble little animals, confined to the mountainous parts of Central Asia.

(C.) The family *Cervidæ* includes the numerous tribe of the true Deer. They are distinguished by the character of their horns, or, as they are called in this tribe, *antlers*, which are composed of solid bone, and are at first mere prominences on the frontal bones, covered with a hairy skin (the *velvet*), having at their base a ring of bony tubercles, which periodically enlarge and compress the nutrient vessels, so that the antlers are shed annually, to be reproduced in a larger and more branched form each year at the breeding season. With the exception of the female reindeer, all the females are destitute of horns. All the deer tribe have a sebaceous gland placed beneath the eye, which secretes a strongly smelling waxy substance. Of the species with round antlers, which are very numerous, only the Roebuck (*Capreolus capræa*), and the Stag, or Red-deer (*Cervus elephas*), are natives of Britain. The Wapiti, or Canadian Stag (*C. Canadensis*), is a larger species, found in North America.

In the following genera, the antlers are more or less flattened and palmated: of these, the Elk or Morse Deer (*Alces palmatus*), which is one of the largest existing species, has the antlers large and very broad, with tooth-like projections on the outer edge. The Elk is found in the northern parts of Europe, Asia, and America. The Reindeer (*Cervus tarandus*), which is so useful to the Laplanders,



Reindeer (*Cervus tarandus*).

is the only species properly domesticated. The reindeer-moss (*Cadonia rangiferina*) forms the chief part of its winter food. It is now confined to the extreme north of Europe, but during the glacial period it ranged as far south as France. The Fallow-deer (*Dama platyceros*), now naturalised in this country, also belongs to this group. The remains of a gigantic species of deer, closely allied to the former, are frequently found in recent deposits, more especially the peat-bogs in Ireland, where it is called the Irish Elk (*Megacros Hibernicus*). Some of the antlers which have been discovered measured thirteen feet between the tips.

(D.) The *Camelopardalidæ* includes only a single living species, the Giraffe or Camelopard (*C. giraffa*). It derives its name from the skin being spotted like a leopard, and its neck long like that of a camel. It differs from the deer in the permanence of its horns, which are covered by hairy skin. The length of its fore-limbs and neck (which contains no more than the normal seven cervical vertebræ) are well known. It measures about eighteen feet in height, and feeds on leaves, which it strips off branches at a considerable height above the ground by its long prehensile tongue. It is gentle and inoffensive,

although capable of powerfully defending itself by kicking. It is a native of Africa.

Giraffe (*Camelopardalis giraffe*).

(E.) The *Cavicornia*—including Sheep, Oxen, Goats, and Antelopes—are the most typical Ruminants, and those of most service to man (*vide* dental formula and characters of a typical ruminant). Their horns are essentially bony prominences from the frontal bone. This bony prominence, or *core*, is permanent, and is covered by a sheath of *horn*. The Cavicornia comprises three families:

The family *Antilopidæ*, which contains upwards of seventy species, are characterised more or less by their simple, cylindrical horns, the core of which is composed of solid bone. They are remarkable for their slenderness of form and swiftness of foot. The speed of the swiftest species surpasses that of every other mammiferous animal. The antelopes are very numerous in individual species, and are chiefly found in Africa; but one species, the Chamois (*Rupicarpa tragus*), inhabits the mountainous parts of the south of Europe. Among the African species are the Eland (*Boselaphus Oreas*), the largest species of the family; the Gazelle (*Gazella Dorcas*), noted for its beautiful eyes, and the Spring-bok (*G. euchore*), which occasionally visits cultivated

Gnu (*Catoblepas Gnu*).

lands during seasons of drought, in innumerable herds, causing devastation wherever they pass. Allied to the antelopes is the curious genus Gnu of South Africa. The body and crupper, also the tail, neck, and mane, resemble those of a horse; whilst its horns are like those of the Cape Buffalo; and its legs are slender and light as those of a

Nyl-Ghau (*Portax picta*).

stag. The Nyl-Ghau (*Portax picta*) is common in the northern parts of India.

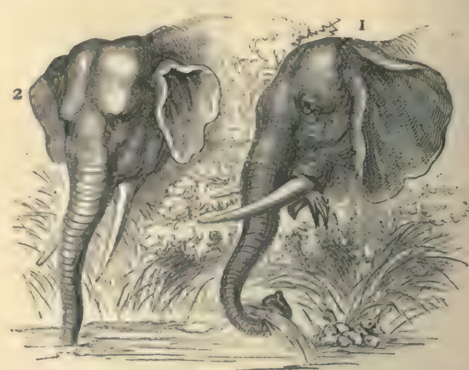
The family of *Ovidæ* includes only the Sheep and Goats, which have horns turned upwards and backwards. Horns are generally present in both sexes, but they are largest in the male. The original stock of the domestic breeds of the goats (*Capra*) appear to be indigenous in Persia, where it inhabits the mountains in large troops. The goats of Angora, Tibet, &c. celebrated for the fine quality of their hair, are merely varieties of the common species (*C. hircus*). The Ibex (*C. Ibex*) is found in the Alps and Caucasus, and is distinguished by the strength and size of its horns. Numerous varieties of the domestic sheep (*Ovis aries*) are known, but their relation to each other is uncertain. The Merino Sheep (a Spanish variety) are specially celebrated for their fine wool. The sheep appears to have been domesticated by man at a very early period; and on the uses of this family to him there is no need to enlarge in this place.

The family of *Bovidæ*, or Oxen, have rounded horns, directed upwards and forwards, the bony core being cellular. They are large animals, with a broad muzzle, robust form, and stout limbs. Without exception, of all the animals which man has reduced to his service, the ox is the most useful. Many breeds or races of oxen exist in different parts of the world, which were probably all descendants from one stock, and yet differ considerably from one another. Most of those inhabiting the torrid zone have a lump of fat upon the shoulders, which increases in size in proportion to the abundance of their food. This is especially remarkable in the Indian or Brahmin Bull, Zebu (*Bos Indicus*), which is regarded as sacred by the Hindus. Amongst the undomesticated species of this family may be noticed the Aurochs, or Lithuanian Bison (*Bos bison*), which was formerly spread over Europe, but is now restricted to the Caucasus; the American Bison, commonly called Buffalo (*Bison Americanus*),

which inhabits all the temperate parts of North America; the Common Buffalo (*Bubalus bubalis*), of which there are several different races, some having been domesticated; the Cape Buffalo (*B. Caffer*), an extremely ferocious animal, with large horns, first directed downwards so as nearly to cover the forehead, inhabiting the woods of Caffraria; and the Musk Ox (*Oribos moschatus*), a species inhabiting the coldest regions of North America, with short legs, and long hair reaching to the ground, which diffuses more strongly than the rest the musky odour common to the whole genus, and which is particularly noticeable in the European bison. The original wild stock of our domestic breeds (*Bos taurus*) is uncertain.

American Bison (*Bison Americanus*).

ORDER 6. *Proboscidea.*—Of this group, the Elephant (*Elephas*) is the only living genus; other species, as the Mammoth and Mastodon, having become extinct in not very remote times. The varieties yet surviving are animals of huge size, which subsist in the great forests of India and Africa by feeding on the leaves of trees and long grass. The incisor teeth in the upper jaw, two in number, grow from persistent pulps, and form enormous tusks. Canines are absent in both jaws, and the molars are few in number, composed of plates of enamel cemented together by dentine. These grinders are in constant progress of removal, and they succeed each other by being pushed forwards from behind in proportion as the tooth before each is worn away. In none of the living forms are there incisors in the lower jaw. The nose is greatly elongated, forming a movable cylindrical trunk (*proboscis*), terminated by a finger-like process, which is very sensitive. The nostrils are placed at the extremity of the proboscis. The 'trunk' is admirably adapted to serve both as a means of laying hold of food and imbibing water: when the capacious nostrils are charged, the animal bends the trunk towards the mouth, and discharges the liquid into its throat. By this organ, the shortness of the neck—rendered necessary by the weight of the head—is fully compensated. The cavity for the brain by no means corresponds with the external form of the skull, the two tables of which are separated by a considerable interval filled with bony cells. The elephant has not a complete hoof, but five toes to each foot, which are only distinct in the skeleton, the whole being enveloped in callous skin, excepting the nails at the extremities. Two species of elephants exist at the present day, both of which inhabit tropical climates—one in Asia (*E. Indicus*), the other in Africa (*E. Africanus*). Remains of the Mammoth (*E. primigenius*) are found chiefly in the north of America and in Siberia; and from a nearly perfect specimen, which was discovered frozen in the ice near the mouth of the river Lena, it appears that this species was adapted to live in cold climates—the skin being densely covered with hair of two kinds. The head of a remarkable fossil form, Deinotherium, has been found in the Miocene deposits of France, &c. It had molars in each jaw, and two incisor teeth in the lower jaw, like the elephant, but these were deflected downwards at right angles to the body of the jaw.



1, Head of Asiatic Elephant (*Elephas Indicus*); 2, Head of African Elephant (*Elephas Africanus*).

ORDER 7. *Carnivora*—are distinguished by characters which point them out as especially formed for the pursuit and destruction of large animals. They possess in the upper and lower jaw six incisor teeth; a large, strong, and pointed canine tooth on each side; and molar teeth which are evidently formed for cutting and tearing, rather than for bruising or grinding. The form of these teeth varies, however, in the different genera, in accordance with their several habits. In the typical species, as the Lion and Tiger, the last tooth but one in the upper jaw, and the last tooth in the lower jaw, are known as *carnassial*, or flesh-teeth, because they have sharp trenchant edges for dividing flesh. In this group, clavicles are wanting or rudimentary. The toes are furnished with strong and sharp claws. The intestines are short, in accordance with the easily digested character of the food.

This order is divided into three sections:

Section 1. *Pinnigrada*, or *Pinnipedia*—comprising the Seals and Walruses, which are Carnivores suited for leading an aquatic life. The fore and hind feet are short, and fitted for swimming, being spread out into fin-like paddles; and the hind-feet are placed far back, nearly in a line with the body, and attached by the integuments to the tail. Their bodies are elongated and fish-like in form, and covered with a close-set fur, sitting flat upon the skin. They pass the greater part of their time in the water, which they only quit to bask in the sunshine and to suckle their young.

The *Phocidæ*, or Seals, have incisor teeth in both jaws, and in them the canine teeth are not excessively developed. The head of the seal resembles that of a dog, presenting the same

mild and expressive physiognomy. These animals seem to possess considerable intelligence; they are easily tamed, and become much attached to

Harp Seal (*Phoca Grœnlandica*), attitude on land.

their feeder. They subsist on fish, which they always devour in the water, closing the nostrils by a kind of valve. They are found chiefly in the Arctic and Antarctic Oceans, but one species (*Phoca vitulina*) is found on the northern shores of Scotland.

The Walrus (*Trichecus rosmarus*), Morse, Sea-horse, or Sea-cow, resembles the seals in the

Walrus (*Trichecus rosmarus*).

form of its body and limbs, but differs in its dentition. The lower jaw has neither incisors nor canines, and is compressed laterally to pass between the two enormous upper canines, which are directed downwards, sometimes attaining a length of two feet. They seem to be used by the animal for hooking up the sea-weeds upon which it partly feeds, and to assist it to get out of the water upon the ice. They are bulky animals, sometimes attaining the length of twenty feet. They are found in all parts of the Arctic Seas, chiefly living in herds.

Section 2. *Plantigrada.*—In the animals of this section, the whole or greater part of the sole of the foot rests on the ground, and the part of the sole so employed is, as a general rule, devoid of hairs. The whole sole being applied to the ground in these animals, is favourable to the maintenance of a firm position, but prevents great activity of progression. The typical family, the Bears (*Ursidæ*), have the molar teeth more or less tuberculated, in accordance with their omnivorous habits. The bears are slow in their movements, and the species which inhabit cold countries pass the winter in a dormant state. Their claws are strong and curved, but not retractile, and the nose is elongated, forming a movable snout. The Brown

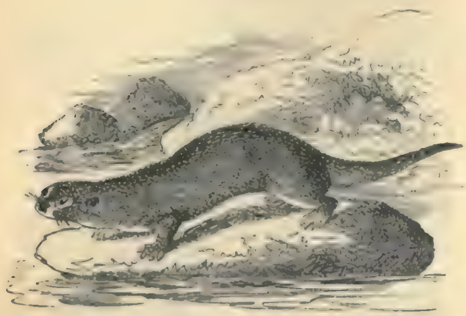
Brown Bear (*Ursus Arctos*).

Bear (*Ursus Arctos*), the commonest species; the Black Bear (*U. Americanus*); the Grisly Bear of America (*U. ferox*); and the White or Polar Bear (*Thalassarctos maritimus*)—which is exclusively carnivorous, and confined to the arctic regions, has the soles of the feet covered with hair, giving it a more secure footing upon the ice—may serve as examples of the bear tribe. Nearly allied to the bears are the Racoons (*Procyon*) of North America. The bones of an enormous species, *U. spelæus*, or Cave Bear, have been found in the caves of Britain and Europe.

The family of the *Melidæ*, or Badgers, have the carnassial tooth formed partly for cutting. These animals have elongated bodies, and, by means of the long claws of their fore-feet, can burrow with great facility. They go in search of food by night, and devour small mammals or vegetables almost indifferently. They can emit a fetid odour at will. The Common Badger (*Meles Taxus*) is a well-known British species. The Glutton, or Wolverine (*Gulo luscus*), which is found in the north of Europe and America, is reputed to be a ferocious animal.

Section 3. *Digitigrada.*—In this group the ends of the toes only touch the ground, the heel being considerably raised into the air, so that thus the limbs can be used to much greater advantage in running and springing than in the former section. Some families exhibit transitional characters between this and the last group, and they are called *Semi-plantigrada;* such are the family of *Mustelidæ*, or Weasels, which, on account of their length of body and their short limbs, being enabled to pass through small openings, are called Vermiformes. They are the most *blood-thirsty* of all the Carnivora; but they are not so well adapted for devouring flesh as the Felidæ. The Weasel (*Mustela vulgaris*) of this country is one of the most sanguinary of all, but it chiefly destroys mice, rats, moles, &c. The Ferret, Marten, and Polecat (*M. putorius*), the last of which is a great enemy to the game-preserve and warren, also belong to the family. All these animals emit a

strong and disagreeable odorous exudation from glands under the tail. The Skunks (*Mephitis*) are an American tribe, and are remarkable for the intensity of their nauseous suffocating stench. The Ermine (*M. Erminia*) and Sable (*M. zibellina*) are valued for their splendid fur. Also belonging



Otter (*Lutra vulgaris*).

to the same family are the Otters (*Lutra*), distinguished by their webbed feet and horizontally flattened tail. The British Otter (*L. vulgaris*) frequents the banks of streams, and lives chiefly upon fish.

The *Viverridæ* is the second family of Semi-plantigrades. They are small animals, with a pointed muzzle, and are either striped or spotted. In the true Civets (*Viverra Civetta*) there is a pouch near the tail which yields the 'civet' of commerce, which is valued as a perfume. They are natives of India and Africa, are easily tamed, and feed partly on fruits. Allied to these is the celebrated Ichneumon (*Herpestes Ichneumon*) of Egypt, which is highly carnivorous, is about the size of a cat, and as slender as a marten. It feeds largely on crocodiles' eggs, by destroying which it prevents the excessive multiplication of these animals. It is easily domesticated, and lives upon small reptiles and mammals.

Connecting the Viverridæ with the Felidæ, is the family of the *Hyænidæ*, which alone of all the

Striped Hyæna (*Hyæna striata*).

Carnivora have only four toes on each foot. The dental formula is:

$$\text{I. } \frac{3-3}{3-3}, \text{ C. } \frac{1-1}{1-1}, \text{ P. } \frac{3-3}{3-3}, \text{ M. } \frac{2-2}{1-1} = 34.$$

the last upper molar being tuberculate. As the fore-limbs are longer than the hind pair, the body slopes towards the hind quarters. Their claws are non-retractile. Their jaws are short and powerful, and peculiarly adapted for crushing bones. They are nocturnal in their habits, and extremely ferocious. Two species are known, which are confined to the Old World—the Striped Hyæna (*H. striata*), which is found in Asia and Africa, and the Spotted Hyæna (*H. crocuta*), which is confined to Africa. The bones of an extinct species (*H. spelura*), or Cave Hyæna, have been found in the caves of Britain, associated with bones of the Cave Bear.

The family *Canidæ*, or Dog tribe, are digitigrade, and have the muzzle pointed, their claws non-retractile, and the tongue smooth, and two of their molars are tuberculate. The animals of this family agree in their greater or less adaptation to a mixed diet. The fore-feet have five toes, and the hind-feet four. The Wolf (*C. lupus*), Fox (*Vulpes vulgaris*), and Jackal (*C. aureus*) are the animals which most nearly approach the dog; and the first of these is regarded by some naturalists as being really identical. The Arctic Fox (*V. lagopus*) is normally of a blackish-brown colour, but on the approach of winter the fur becomes white and very long, forming an excellent protection against the cold in those high latitudes. The breeds of the Common Dog (*Canis familiaris*) are all believed to have had the same origin.

The last family of the Digitigrada is the *Felidæ*, or Cat tribe, which are characterised by their rounded head and powerful jaws, their retractile claws—which, when not in use, are drawn within a sheath so as to prevent them from being blunted—and the adaptation of their teeth for cutting. Only the last molar in the upper jaw is tuberculate. The fore-feet have four toes, and the hind-feet five. Their tongue is roughened by horny papillæ, thus rendering it more efficient for rasping the flesh off the bones of their prey. They steal upon their prey unawares, and seize it with a sudden spring, often slinking off when once baffled. Most of them are sufficiently well known to render any peculiar description unnecessary. It may, however, be remarked, that some species are found in almost all tropical and temperate

Bengal Tiger (*Felis tigris*).

countries, and that those of different parts of the globe *represent* each other in a remarkable

manner. Thus, the Lion (*Felis leo*) and Tiger (*F. tigris*) are inhabitants of Africa and tropical Asia; in America, they are replaced by the Puma (*F. concolor*) and Jaguar (*F. onca*), which are confined to that continent. In the same manner, we find the Panther and Leopard (*F. leopardus*) spread over tropical Asia and Africa; the Ounce, inhabiting the Asiatic mountains; the Caracal, in Turkey and Persia; and the Lynx, in Northern Europe. These are represented by the Ocelot in South America, the Lynx of Canada (differing from the European), and other less-known species. The Lynxes have short tails and a pencil of hair at the tip of their ears, while the Cats (*F. catus*) have a long tail, and the ears want the pencil of hair.

ORDER 8. *Rodentia*—take their name from their gnawing habits, for which they are fitted by the possession of two long curved incisors in each jaw. There are no canines, and a considerable interval intervenes between the incisors and the molars, which are few in number. These incisors are constantly wearing away, but as constantly growing from persistent pulps; so that when one is lost or broken, its opposite, having nothing to wear it down, becomes developed to an enormous extent. The incisor teeth consist anteriorly of a hard plate of enamel, and posteriorly of a softer substance (dentine), which wears away more rapidly than the enamel, so that the teeth are always kept sharp, and bevelled away behind, so as to be chisel-shaped. To assist the action of these teeth, the lower jaw is articulated to the skull by a transversely elongated condyle, which allows it to move backwards and forwards.

Family 1. *Leporidæ*—are distinguished by the presence of two small incisors behind the rodent teeth. The form and habits of the typical genus are sufficiently well known in the Hare (*Lepus timidus*) and Rabbit (*L. cuniculus*) of this country. There is a species, *L. variabilis*, or Alpine Hare, in this country, whose fur is brown in summer, and white in winter. The *Lagomys*, or Rat-hare, has the fore-legs almost as long as the hind. It is a native of the colder regions of the north, and stores up a large quantity of fodder for the winter.

Family 2. *Cavidæ*—in which the body is covered with hair, and the tail is short, contains the Capybara (*Hydrochærus capybara*), the largest animal of the order, being about three feet in length, and of the size of the Siamese pig. Its semi-aquatic habits are shewn by the webbing of the feet. It is found on the sides of nearly all the rivers of South America. The *Cavia Aperæa*, or Guinea-pig, a South American species, is now quite domesticated in Europe. The Agouti (*Dasyprocta*) also belongs to this family.

Family 3. *Hystricidæ*—including the Porcupine, which are distinguished by being armed by stiff and pointed quills, or spines. The name porcupine is corrupted from the French *porc-épine*, a term expressive of the pig-like aspect and grunting voice of these animals, as well as of their spiny covering. They live in burrows, and have very much the habits of rabbits. The best known species inhabits the south of Italy, Sicily, and Spain. In the Common Porcupine (*Hystrix cristata*), the tail is non-prehensile; but in the American genus, *Cercolabes*, which is

Porcupine (*Hystrix cristata*).

fitted for an arboreal existence, it is long and prehensile.

Family 4. *Castoridæ*.—The Beaver (*Castor fiber*) is probably the type. It is distinguished from all other rodents by its horizontally flattened tail, which is of a nearly oval form, and covered with scales. The hind-feet are webbed, by means of which and the tail these animals obtain considerable swimming powers. They chiefly subsist on bark and other hard substances, and, owing to the size and strength of their incisor teeth, they can fell trees of considerable size, of which they use the bark and twigs as food, employing the stems in the construction of their remarkable habitations. The flattened tail is employed by them as a kind of trowel, with which they plaster the walls of their houses. The Beaver is an aquatic and social

Beaver (*Castor fiber*).

animal, and is hunted for the sake of its skin, and for the substance, *castoreum*, which is secreted by peculiar glands, and is employed in medicine.

Family 5. *Muridæ*—are the smallest and most prolific of the Mammalia. In this family, the tail is long, and thinly covered with hair, though sometimes scaly. No undomesticated animals are better known than Mice and Rats. The Brown Rat (*Mus decumanus*), which is believed to have originally come from Persia, is speedily replacing the Old English or Black Rat (*M. rattus*), which, being of smaller size, is not a match for the usurper. The Harvest-mouse (*M. messorius*), the Long-tailed Field-mouse (*M.

sylvaticus), and the Common Mouse (*M. musculus*) are British species, and are too well known to require any description. A great number of species exist in different parts of the world, differing little from each other. Belonging to the same family are the Lemmings or Scandinavian Rats (*Myodes lemmus*), which are remarkable for their occasional migrations in immense bodies. They are stated to advance in a straight line, regardless of rivers and mountains; and while no insurmountable obstacle impedes their progress, they devastate the country through which they pass. The Hamsters (*Cricetus*) are nearly allied to the rats, but their tail is short and hairy, and they have cheek-pouches, in which they can stow away grain for transport to their nests. They abound in Asia, but one species is found in the sandy plains of the north-east of Europe. The Voles (*Anicola*), including the Short-tailed Field Mouse (*A. agrestis*), and the Water Rat (*A. amphibia*) are forms intermediate between the *Muridæ* and *Castoridæ*.

Family 6. *Dipodiæ*, or Jerboas—characterised

Jerboa (*Dipus Ægyptius*).

by the enormous length of the hind-legs as compared with the fore-limbs, which are very short, and armed with claws with which they dig burrows in which they live, like most of the species of this order. They live in troops, and inhabit Russia and North America. They hop along on their hind-legs much after the manner of a kangaroo.

Family 7. *Myoxidæ*—represented by one British species, the well-known Dormouse (*Myoxis avellanarius*), which must not be confounded with the true Mouse, nor with the Shrew-mouse.

Family 8. *Sciuridæ*, or Squirrel tribe.—The characters and habits of the Common Squirrel (*Sciurus vulgaris*) are too well known to require description. The *Pteromys*, or Flying Squirrel, is aided in leaping from tree to tree by an extension of the skin of the flank between the fore and hind legs, which serves as a parachute. It is an inhabitant of Southern Asia and Polynesia. The Marmots (*Arctomys*) differ from the squirrels in being fitted for living on the ground, and even in burrows beneath it. A remarkable species is the *A. ludovicianus*, or Prairie Dog, or Barking Squirrel, so called because its bark resembles that of a small dog. It lives in great troops in immense burrows on the plains of the Missouri. They are connected with the former tribe, however, by an elegant little animal termed the

Flying Squirrel (*Pteromys volucella*).

Ground-squirrel (*Tamias*), partaking of the habits of both: this is a native of Eastern Europe. Like the Dormice, all the members of this family pass the winter in cold climates in a state of lethargy. The rodents of the first, second, and third families are destitute of clavicles, while the remaining families possess them.

ORDER 9. *Insectivora*—are small animals, subsisting chiefly on insects and vegetable substances. Their molar teeth are provided with numerous small cusps, suited for bruising insects. They are all nocturnal and subterranean in their habits, and most of them spend the winter in a state of sleep. Clavicles are present in the entire order.

Family 1. *Erinaceidæ* (Hedgehogs).—These animals are called Hedgehogs because they prefer the roots of hedges as their hiding-places, and from a superficial resemblance which they bear to pigs. Nature has provided them with a bristly coat of armour, which, by strong cutaneous muscles, they can draw over every part of the body, or every part which is accessible, so as effectually to protect themselves from their enemies. They roll themselves up into a ball at the approach of danger. They live on fruit and the eggs of small birds, and are torpid in winter. Our only British species is the *Erinaceus Europæus*, which is too well known to require description.

Family 2. *Talpidæ* (Moles) live chiefly underground, feeding on insects, worms, and roots. Their feet, which are provided with strong curved claws, are admirably adapted to their subterranean mode of life. From the smallness of their eyes, which are scarcely perceptible, it was long considered that the Moles were blind; but it is now ascertained that they are by no means deficient in the sense of sight. Moles have no external ears; but, from the tympanum being large, their sense of hearing is nevertheless very acute. The only British species is the Common Mole (*Talpa Europæa*).

Family 3. *Soricidæ* (Shrews) are small animals, having soft hair, well-developed eyes, and external ears, and the feet are not adapted for digging.

They are very widely distributed, and the Common

Common Shrew (*Sorex araneus*).

Shrew (*Sorex araneus*), and Water Shrew (*S. fodiens*), may serve as examples.

ORDER 10. *Cheiroptera* (Bats)—are suited for an aerial life, and have the four digits of the fore-limb greatly elongated, the thumb being short, and terminated by a hook-like nail, which serves the animal for climbing on precipices. Across the lengthened fingers is stretched a membrane, which is continuous with the sides of the body, and extended between the fore and hind limbs. The hind-limbs are short, and all the toes are furnished with claws, by which the bats suspend themselves from the trees or walls on which they rest, hanging with the head downwards. The bats have the power of true flight, like birds, and, from some peculiar sensitiveness of wing, they can make their way, while deprived of eyesight, and even of hearing, among a confused variety of objects, without ever coming in contact with any. In many of the insectivorous bats, the organ of smell is furnished with curious leaf-like appendages, formed of the integument, doubled, folded, and cut into curious and most grotesque forms. The *Cheiroptera*, inhabiting temperate climates, all remain in a torpid state during the winter. They are nocturnal in their habits, and may be divided into two divisions, according as their diet consists of insects or of fruits.

Section (A). *Insectivora*—which feed upon insects, and have the molar teeth tuberculate, like the order Insectivora, and the intestines short. It comprises three families :

Family 1. *Vespertilionidæ*—which includes most of the bats of temperate climates. At least fifteen species exist in this country, the largest of which

Long-eared Bat (*Plecotus auritus*).

is the Noctule, or Great Bat (*Vespertilio noctula*), which seeks its retreat under the eaves of houses and in hollow trees, and measures fifteen inches in the expanse of wing. The Long-eared Bat (*Plecotus auritus*) is not uncommon, and is distinguished by the character implied in its name. The commonest species is the Pipistrelle (*V. pipistrella*).

Family 2. *Rhinolophidæ*—contains the Greater and Lesser Horse-shoe Bats, which are found in the darkest and most secluded retreats of our own country ; their name is derived from the complex leaf-like form of the anterior nasal appendage. In the *Megaderma*, an Indian and African genus, the ears are so large as to unite over the forehead.

Horseshoe Bat (*Rhinolophus Ferrumequinum*).

Family 3. *Phyllostomidæ*—which have a nasal leaf-like appendage, and short ears. It includes the well-known Vampire Bat (*Phyllostoma spectrum*), which exhibits a considerable degree of ferocity, and has the habit of sucking blood from sleeping animals. It attains a considerable size, the wings, when expanded, measuring about two feet and a half. The Vampires are confined to South America.

Section (B). *Frugivora*—in which the molar teeth have flattened crowns, suited for grinding fruits, and the stomach is complex. It includes but one family, the *Pteropidæ*, or Fox-bats, which have the ears short, the head long and pointed, and bearing some resemblance to that of a fox. The tail is either short or absent. They are widely diffused throughout warm climates, and contain some of the largest species of the order —the *Pteropus edulis*, or Kalong of Java, measuring five feet across its expanded wings. Where they abound, they are eaten as food by the inhabitants. They are specially characteristic of the Pacific Archipelago.

Head of Pteropus.

ORDER 11. *Quadrumana*, or Monkeys—have an interest for us beyond most orders of Mammalia, on account of their being the animals nearest to man in external form and in intelligence. They are omnivorous animals, dwelling chiefly in the forests of warm countries, and spending much of their time on the branches of trees, among which they are well fitted to move by reason of the grasping power of their extremities. They are characterised by having the innermost toe of the hind-limb separate from the other toes, and opposable to them, so that the hind-feet become converted into prehensile hands. When the innermost toe of the fore-limb is present, it also is opposable to the other toes, so that the animals are really *four-handed*, hence the name. All of these, like man, possess three sorts of teeth ; the canines, in the full-grown animal, are much more developed than in man ; and there are intervals between them and the other teeth

which are not present in his jaws, but exist in all other Mammalia.

Owen has divided them into three groups, according to their anatomical characters and their geographical distribution :

Section (A). *Strepsirhina*, or *Prosimiæ*—comprising the Lemurs and their allies, have the muzzle prolonged, and the *curved* nostrils placed at its extremity. All the four thumbs are well developed and opposable, and the fore and hind limbs have five toes each. The claw-like aspect of the nail of the second digit of the hind-limb is one of the most easily recognised characters of the section. Madagascar is their chief geographical centre.

In the true Lemurs (*Lemuridæ*), all the digits except the second toe of the hind-feet are covered with flat nails. They have very large and handsome prehensile tails, which are elevated when the animal is in motion. They are about the size of a cat, but have longer limbs, and are exclusively confined to the forests of Madagascar, where they spring about from tree to tree in search of their food, which consists principally of fruits. They are nocturnal in their habits, and are exceedingly active.

The *Nycticebus* or *Loris*—of which the *Stenops tardigradus*, or Slow-paced Lori, is the best known example—have short ears, no tail, and large approximating eyes, and are inhabitants of India and the Eastern Archipelago. They are nocturnal in their habits, and very slow in their movements, hence they are called 'Slow Lemurs,' and they feed principally on insects.

With this group may also be placed the Aye-aye (*Cheiromys Madagascarensis*), which has no canine teeth, and a considerable interval between

Aye-aye (*Cheiromys Madagascarensis*).

its incisors and the molars. It is about the size of a squirrel, and has a bushy tail. It feeds upon larvæ and insects, which it picks out of the crevices of the bark of trees by night with its long slender fingers.

For convenience, we may place in this group a remarkable animal, which seems to connect the Insectivora with the Quadrumana. It is the *Galeopithecus*, or Flying Lemur, which has the integument stretched from the nape of the neck to the fore-limb, and from the fore-limb to the hind-limb. This is simply an integumentary expansion, similar to that of the Flying Phalanger and the Flying Squirrel, with which the animal can take leaps from tree to tree. It feeds upon insects, fruit, and eggs, and inhabits the Indian Archipelago.

Section (B). *Platyrhina*, or New-World Monkeys.—In the animals of this group, owing to the septum of the nose being broad, the nostrils are placed widely apart. In general, the thumbs of the anterior members are not opposable, and they are sometimes absent. Their tails are generally prehensile. They are confined to the woods of South America. They are divided into two families.

Family 1. *Halpalidæ.*—They have ten grinders in each jaw, like the Old-World monkeys, their dental formula being :

$$\text{I.}\ \frac{2-2}{2-2},\ \text{C.}\ \frac{1-1}{1-1},\ \text{P.}\ \frac{3-3}{3-3},\ \text{M.}\ \frac{2-2}{2-2} = 32.$$

Their tail is long, and usually bushy, but never prehensile. The thumb of the hind-foot has a flat nail, but all the other toes are unguiculate. They are all diminutive animals, of pleasing forms, and very active movements. The best known species is the Common Marmoset (*H. penicillata*), which is often domesticated or kept as a pet. Upwards of thirty species have been described.

Family 2. *Cebidæ*, in which the grinders are more numerous than in the Catarhina and in Man, the dental formula being :

$$\text{I.}\ \frac{2-2}{2-2},\ \text{C.}\ \frac{1-1}{1-1},\ \text{P.}\ \frac{3-3}{3-3},\ \text{M.}\ \frac{3-3}{3-3} = 36.$$

They have neither cheek-pouches nor callosities, which are usually present in the Old-World Monkeys. The tail is prehensile, and capable of being twisted round branches so firmly as entirely

Spider Monkey (*Ateles paniscus*).

to support the weight of the animal. They subsist

chiefly on vegetable substances. They are found in troops in the vast forests in South America, climbing amongst the trees. The largest of them are the *Myceti*, or Howling Monkeys, which derive their tremendous powers of voice from a sort of hollow drum connected with the larynx, which is peculiar to them amongst the Cebidæ. Humboldt says that the noise so produced can be heard at the distance of nearly a mile. They are shaggy animals about the size of a fox. The *Ateles*, or Spider Monkeys—remarkable for the length of their prehensile tails, and for the absence of thumbs in the anterior extremities—the Capucin Monkey (*Cebus*), and the Squirrel Monkey (*Callithmi*), all belong to this family.

Section (C). *Catarhina*, or Old-World Monkeys. This is the highest section of the Quadrumana, and the animals composing it are entirely confined to the Old World. The nostrils are oblique, and placed close together. The thumbs of all the feet are well developed and opposable, except in the genus *Colobus*, in which the anterior thumbs are absent. The number of teeth is the same as in man, but they are in an uneven series, interrupted by an interval. The canines, especially in the males, are long and pointed. The tail is never prehensile, and is sometimes absent. They have *natal callosities*, or hard spots on their haunches destitute of hair. Cheek-pouches are often present. They are all natives of Asia or Africa, except the monkey inhabiting the rock of Gibraltar. They are divided into three groups :

Group 1. The *Long-tailed Monkeys*, in which the tail is long, and there are both callosities and cheek-pouches, including the genus *Semnopithecus*, of which *S. entellus*, or Sacred Monkey of the Hindus, is the one best known. It is considered a capital crime to kill one of these monkeys. In the genus *Colobus* alone, the thumb of the fore-foot is absent. The species of the genus *Macacus*, which have a short tail (Macaque), are found in Asia and Africa; but one, the *M. Inuus*, or Barbary Ape, is found on the Rock of Gibraltar, and it is the only wild monkey in Europe.

Group 2, including the Baboons (*Cynocephalus* and *Papios*), in which the tail is short, the muzzle protuberant, and the aspect ferocious. The canine teeth are generally large and strong.

Mandrill or Rib-nosed Baboon (*Papio Mormon*).

The callosities are of great size, and usually adorned with some bright colour. The Baboons have a large bag connected with the larynx, by the resonance of which the power of their loud and discordant cries is greatly increased. They can run upon all-fours with great ease. They all inhabit Africa, and one of them, the Mandrill (*Papio Mormon*), is a ferocious-looking animal, about the height of a man, and distinguished from other baboons by a ridge on its cheek, which is covered with a naked skin of a bright-blue colour. In the Drill (*P. leucophæa*), this ridge is black.

Group 3, containing the Anthropoid or Anthropomorphous Apes, or those which approach most nearly in their structure to man. These apes are distinguished by the absence of a tail and cheek-pouches—the callosities are sometimes absent also—and by the predominance in length of the fore-arms over the hinder ones. The thumbs of the hind-limbs are opposable, and the animal can assume a semi-erect attitude.

In the Gibbons, or Long-armed Apes (*Hylobates*), which are the smallest and slenderest of the man-like apes, the arms are so long that they touch the ground when the animal is in a semi-erect attitude. In this genus, callosities are present. The best known is the *H. syndactylus*, or Siamang, and there is pretty good evidence that it assumes the erect position. Several species are found in Asia, Java, Borneo, &c. In the Orang (*Simia satyrus*), the haunches are covered with hair, and there are neither callosities nor cheek-pouches. The arms are excessively long, reaching below the knee when the animal is erect. There is a remarkable difference between the young and the adult form of the skull—the young bearing the greatest resemblance to that of man, whilst in the adult the muzzle is so much prolonged, and the canine teeth are so much developed, as to give the face much more the aspect of that of the baboon. It is more sluggish in its movements than the active and agile Gibbons. It is about four feet in

Gorilla (*Troglodytes Gorilla*).

height, and clothed with a reddish-brown fur. It is confined to Borneo and Sumatra, where it

receives from the Dyaks the name of *Mias*. The genus *Troglodytes* contains the Chimpanzee and the Gorilla. The latter, which is excessively strong, and extremely ferocious, is a native of New Guinea, and is now regarded as the most human of all the anthropomorphous apes. It attains a height of fully five feet, and when erect, the arms reach to the middle of the leg. The two hinder limbs are not intended by nature to serve as a support to the entire weight of the animal. It only puts the outside to the ground, and seems awkward and insecure unless it has the fore extremities also employed in its support or in progression.

By Linnæus, the Quadrumana and Bimana were united under one order, the *Primates*, and this arrangement is followed by some eminent modern zoologists, but chiefly by the advocates of the theory of progressive development.

ORDER 12. *Bimana*.—At the head of the Mammalia, and consequently of the entire Animal Kingdom, stands the order BIMANA, implying Two-handed Animals, but in reality composed of but one genus—MAN (*Homo*). In this place we have to consider man solely as a part of the Animal Kingdom. The study of man's psychical endowments and his physical structure belongs to other departments of science. Zoologically considered, man is distinguished by his habitually erect posture, and by the two hinder limbs being devoted solely for support and progression, while the two anterior extremities are fitted for prehension alone. By the upright position, his upper extremities are left at entire liberty, whilst his organs of sense are most favourably situated for observation. The hand of man is adapted to a far greater variety of purposes than that of the monkeys, in which it is most perfect; its power consists chiefly in the size and strength of the thumb, which can have its tip brought into opposition with that of any of the fingers; and all these are capable of being moved separately. In none of the monkeys can the thumb be opposed to the fingers with any degree of force; and in many, their tips cannot be brought into contact; so that, though admirably adapted for clinging round bodies of a certain size, such as the small branches of trees, their hands can neither seize very minute objects, nor support large ones. In man, also, the toes of the fore and hind limbs are covered by nails, but in the hind-limbs the great toe is not opposable to the other digits. The foot is broad, and the whole sole is applied to the ground in walking.

The dentition consists of thirty-two teeth in an even and uninterrupted series, without any interval, the dental formula being:

$$\text{I.}\ \frac{2-2}{2-2},\ \text{C.}\ \frac{1-1}{1-1},\ \text{P.}\ \frac{2-2}{2-2},\ \text{M.}\ \frac{3-3}{3-3} = 32.$$

The brain of man is much more highly developed; its convolutions are more numerous, more pronounced, and its size is greater relatively than in any other mammal. He is the only terrestrial mammal whose body is not furnished with a covering of hair. Man is distinguished from other mammals not so much by his anatomical and structural qualities as by his high psychical endowments. He may be comprehensively described as a being fitted to live upon almost all kinds of food, and in every part of the earth except those constantly under snow; of an extraordinary intelligence, and tendency to social life; eminent in power over all other animals, and endowed with the greatest ability to turn the objects and forces of physical creation to his own benefit. Besides all this, we believe there is a spiritual being within us, vouchsafed to no other species, by which we are brought into peculiar relations to the Divine Author of nature, and which will survive the frail tenement in which we live.

Flying Fox or Roussette (*Pteropus rubricollis*).

NATURAL PHILOSOPHY—MATTER, MOTION, AND HEAT.

As man contemplates the bodies that make up the universe, and the endless movements and changes they undergo, he becomes impressed with the conviction that these *phenomena* (appearances), as they are called, are not simply a collection of individual things ruled by chance, but that there are fixed connections—in other words, order and uniformity among them; and he feels irresistibly impelled to trace out these connections, or *laws* of nature, as they are called, wherever they can be discovered. In this pursuit we have Natural Philosophy in its widest sense.

Some phenomena depend upon the peculiar kind of substance of which the body manifesting them is composed, and consist in changes of its constitution. The facts of this class form the separate science of *Chemistry*. Organised bodies—that is, plants and animals—also manifest a peculiar set of appearances which are summed up in the word *life*. The consideration of *vital* phenomena belongs to the department of science called *Physiology*, sometimes *Biology*.

But there is a large and important class of phenomena of a much less special kind, and which belong to matter in general, and to all bodies composed of it, whatever be their peculiar constitution, and whether organic or inorganic. Thus, a stone, a piece of sulphur, a drop of water, a plant, an animal, all fall to the earth if unsupported, are all capable of being divided into small parts, all reflect more or less light, &c. It is the investigation of universal laws of this kind, where no change of constitution is concerned, that constitutes Natural Philosophy, in its narrower sense; for which the term *Physics* is now more generally used, as being more precise. Of those physical phenomena, again, some have a higher generality than others, and it is these most general laws of the material world that naturally fall to be discussed in this introductory treatise. They may be arranged under the heads of *General Properties of Matter*, *Motion and Forces*, and *Heat*.

GENERAL PROPERTIES OF MATTER.

Matter, or that which composes all bodies, has certain *properties;* by which is meant, that it has the power of making certain impressions upon our senses, or of exciting in us *sensations*. As to what matter is in itself, beyond its power of affecting our senses, we know nothing. The something, whatever it is, in which this power is conceived to reside, is called *substance*. Some philosophers deny the existence of anything beyond the properties. So far as natural science is affected, the question is of no moment; what really concerns us is, how matter appears and acts, and not what it is. The more important of the properties of matter are—Impenetrability, Extension, Divisibility, Indestructibility, Inertia, Porosity, Compressibility, Elasticity, Attraction, States of Aggregation, Malleability. We shall describe and illustrate them in succession, classing such qualities together as seem to be naturally connected.

Impenetrability is that quality of bodies by virtue of which each occupies a certain portion of space, to the exclusion of all other bodies; it expresses the fact that two bodies cannot be in the same place at the same time. In the popular sense of the word, matter is anything but impenetrable. The hand can be thrust into water, a nail can be driven into wood. But all these are instances merely of displacement. That the most movable and unsubstantial substances, when displacement is prevented, occupy space as effectually as the most solid, is seen in a blown bladder, or in an air-cushion. This property of air is taken advantage of in the diving-bell.

Extension or *Magnitude*, and *Form*.—Magnitude or size is one of those simple ideas that do not require or admit of explanation, because there is nothing simpler to explain them by. It is chiefly by their extension that bodies make themselves known to our senses.

Divisibility.—There is no known limit to the divisibility of matter. A chip of marble may be broken from a block, and that chip may be crushed to powder. The smallest particle of this powder discernible by the naked eye, when examined by the microscope, is seen to be a block having all the qualities of the original marble, and capable, by finer instruments, of being divided into still smaller blocks, which may be again divided; and so on, with no other limit than the fineness of our senses and instruments.

The unlimited degree to which matter may be comminuted is yet more strikingly seen in other ways. When a substance is dissolved in a liquid, or water rises in vapour, the particles become so minute as to be invisible with the most powerful magnifiers. The microscope, again, has revealed the existence of animals, a million of which would not occupy more space than a grain of sand. Yet these animalcules, as they are called, have limbs and organs, and display all the appearances of vitality. How shall we conceive the smallness of the tubes or vessels in which their fluids circulate, and the minuteness of the particles of matter composing these tubes and fluids!

Divisibility thus extends far beyond the limits perceptible to the senses. Are we, therefore, to assume that it is without limits—that matter is infinitely divisible? This would be a rash assumption. On the contrary, there are many reasons for believing that there is a limit somewhere, and that there are ultimate particles, of a determinate size and shape, incapable of further subdivision. These assumed ultimate particles are called *atoms*, from a Greek word signifying indivisible. Their existence is inferred from a number of facts connected chiefly with crystallisation and chemical combination, which cannot be otherwise explained. These ultimate particles or atoms, it is assumed, first form definite groups,

varying in number and arrangement in different substances; these groups are called *molecules*, and bodies are held to be built up of aggregations of such molecules.

But whether the ultimate component particles of bodies have a fixed size and shape or not, we know that they are *indestructible.* This is not, indeed, what a first impression suggests, for nothing is more common than for bodies to decay, dissolve, evaporate, and disappear. But it can be proved that in no case is anything lost. Water disappears in invisible vapour when heated; but if the vapour is carefully collected and cooled, the water reappears without loss of weight. The substance of the coal burned in our fires is not annihilated; it is only dispersed in the form of smoke or particles of soot, gas, and ashes or dust.

Inertia or *Inactivity.*—The term inertia or inactivity is meant to express the fact, that an inorganic body has no power to change its state. If it is at rest, it cannot put itself in motion; if it is in motion, it cannot bring itself to rest; any change must come from some external cause. It hardly gives a correct notion to say that bodies are quite passive to a change of state; for they *resist* the change, with a force depending upon the mass of matter they contain and the amount of motion sought to be given to them or taken away. No one term conveys all that is meant; *persistence* has been suggested as less objectionable than inertia, inactivity, or passiveness.

The following instances illustrate the action of this property of matter: A great force is necessary at first to set a vehicle in motion; but when once this is effected, it goes onward with comparative ease; so that, in fact, a strong effort is necessary before it can be stopped. If a person be standing in it when it is suddenly set agoing, his feet are pulled forward, whilst his body, obeying the law of inertia, remains where it was, and he accordingly falls backwards. On the other hand, if the vehicle be suddenly stopped, and the individual be standing in the same position as formerly, the tendency which his body has to move forward—for it acquired the same motion as the carriage by which it was borne along—will cause him to fall in that direction. A man jumping from a coach at full speed falls prostrate on the ground; for his body has the same motion as the coach; and when the feet arrive at the ground, they are arrested, while the rest of the body moves on; and thus he finds himself thrown down.

The process of beating a carpet, or dusting a book, rests on the same principle. When a dusty book is struck against a table, the book and the dust are first brought into rapid motion together, and the book being then arrested by the table, the dust continues in motion by its inertia, and is thus detached.

It is a common impression with those who have never reflected upon the subject, that bodies are more inclined to rest than to motion. This arises from the fact, that while no body begins to move or increase its speed without some cause for the change being apparent, all the motions that come within our observation on the surface of the earth do actually come to an end, most of them gradually, and without any very apparent cause. Thus the notion is begotten, that rest is the natural state to which all matter, when left to itself, seeks, as it were, to return. But a little consideration shews us that the retardation and stoppage of motion are as dependent on causes as its beginning is. A ball rolled on the rough earth soon stops; on a wooden floor, it continues longer; and on smooth ice, longer still. This shews that one cause of the arrest of terrestrial motions is friction. Another constant impediment is the resistance of the air. A pendulum set in motion in an exhausted receiver, will continue to swing, without the help of clock-work, for a whole day, having nothing to resist its motion but the small amount of friction at its point of suspension. Finding thus that motion is prolonged in proportion as we diminish obstructions to it, though we can never completely remove them, we conclude, that if they were removed, motion once begun would go on for ever.

It is in the heavenly bodies, however, that we find complete proof of this truth. They move without friction, and unresisted by any fluid manifest to the senses, and no appreciable slackening of their speed has yet been detected; they retain the amount of motion they had from the beginning.

Compressibility, Contractibility; Expansibility, Dilatability.—When a body is forced by mechanical pressure into less space than it previously occupied, it is said to be *compressed;* when any cause not mechanical, such as loss of heat, causes its volume to diminish, it is said to be *contracted. Expansion* and *dilatation* are used to express enlargement of volume or bulk. Now, all bodies whatever are liable to these two opposite kinds of change—without any addition to, or deduction from, the matter composing them. Even those substances which we consider as types of solidity are compressible. A piece of iron, when squeezed in a vice or hammered, loses in bulk, and becomes more compact.

The most compressible substances are air and other gases. A moderate pressure will force a quantity of air confined in a vessel into half its volume; and as the pressure is increased, the volume goes on diminishing almost without limit. By pressure and cold combined, several gases have been reduced to the liquid form. Compared with gases, or even solids, liquids have little compressibility. (See HYDROSTATICS.)

Expansion or dilatation is chiefly seen in the case of heat being applied to bodies (see page 204). Gases are unlimitedly dilatable. (See HYDROSTATICS and PNEUMATICS.)

Elasticity.—Some bodies, when compressed, recover their former size when the pressure is removed. Such bodies are called *elastic;* and those which remain as the compressing force put them, are *non-elastic.* Air and other gases afford the best examples of elasticity. Caoutchouc, ivory, and steel are among the most elastic of solid substances. But no solid body is perfectly elastic, nor are any completely non-elastic; so that elasticity may be considered as general a property of matter as compressibility. The cause of elasticity is not well understood.

Porosity and *Density.*—In common language, a pore is a small hollow space or interstice between the particles of a body, large enough to be seen, or to admit the passage of liquids or gases. In this sense, some substances, such as sponge, wood, sugar, &c. are called *porous*, and others

are contrasted with them as *solid*. But experiment and reflection lead us to the conclusion that all bodies are porous. We have seen that bodies are made up of indefinitely small molecules; and the fact that all bodies admit of compression and expansion, makes us believe, that in no case do these molecules fill the whole space occupied by the body, but have interstices of greater or less size between them; so that when a body is compressed, its molecules are only more closely packed. There is nothing, then, that is not porous, in this sense; and one body is more dense or solid than another, only because it is less porous. *Density* thus means the comparative closeness of the molecules of a body; and a dense body contains, bulk for bulk, more molecules, that is, more matter, than one that is less dense, or, in other words, more porous. As weight depends upon the quantity of matter, density and weight thus go together.

In comparing the densities of different substances, that of distilled water is taken as a standard, and called 1. If a cubic inch, then, of any substance weigh twice as much as a cubic inch of water, its comparative density is expressed by 2; and this is generally called its *specific gravity*. The following table exhibits the specific weights of a few of the more familiar substances:

Platinum, coined	22·100	Flint Glass	3·375
Gold, coined	19·325	Boxwood	1·330
Mercury	13·598	Oak, old	1·170
Lead	11·352	Milk	1·030
Silver	10·474	Sea-water	1·026
Copper, hammered	8·878	Water, distilled	1·
Iron, wrought	7·788	Alcohol, absolute	·800
" cast	7·207	Beech, dry	·590
Diamond	3·520	Cork	·240

Attraction and *Repulsion*.—The term attraction is applied to a great many phenomena, which we must regard as of different kinds, or produced by different causes. The force, whatever it is, that makes a stone fall to the earth, is called the *attraction of gravitation*, because it is the cause of *gravity* or weight. Sir Isaac Newton demonstrated that the same force acts on the moon, drawing it towards the earth; and on the earth, drawing it towards the sun: or rather, that the attraction between any two heavenly bodies is mutual, making them approach each other. It is now established as a fundamental law, not only of our globe, but of the universe, that every atom of matter is attracted towards every other atom. The effects of this law, in causing the fall of bodies and weight, will be considered under Terrestrial Gravity in this number. See also ASTRONOMY.

When a loadstone or a magnetic needle is brought near to a piece of iron, the two bodies, if free to move, will come together and adhere to each other. Also, if a stick of sealing-wax is rubbed with silk, it will draw a light feather to it. These two forms of attraction—the *magnetic* and the *electric*—will be particularly described in the numbers on ELECTRICITY and MAGNETISM.

The kinds of attraction already mentioned act between bodies at a distance, as well as near. But there are forces at work in matter which act only at insensible distances, and between the adjacent atoms and molecules; they are hence called *atomic forces* and *molecular forces*. They are spoken of under the names of Cohesion, Adhesion, Repulsion, and Chemical Attraction.

Cohesion is that force that binds together particles or molecules of the same kind of matter, so as to form masses or bodies. Without some force to hold the molecules together, we could not have bodies, but mere heaps, as of sand. Cohesion acts only when the particles are at distances so minute as to be insensible to us: when removed beyond that distance, it has no influence whatever; and when the molecules of a solid body are once separated, it is in most cases impossible to bring them near enough again to make them cohere.

The three *states of aggregation*, as they are called—that is, the *solid*, *liquid*, and *aëriform*—are owing to differences in the strength and manner of acting of cohesion. It is commonly said that its force is greatest in solids, less in liquids, and altogether wanting in gases. But this account does not explain all the differences of these states. If the smallest quantity of air, or any other gas, is admitted into the exhausted receiver of an air-pump, it does not remain at the bottom, but spreads itself instantly and uniformly through the whole space, as if its particles wished to remove from one another as far as possible. There seems no limit to the space over which the smallest portion of gas will thus spread itself, so that it shall be found in every part of it. We cannot help inferring from this, that the molecules of a gas, instead of attracting, actually *repel* one another with a force sufficient to overcome their own weight—for gases have weight as well as solids and liquids. The dilatation of solid bodies by heat, and the recoil of elastic bodies after compression, would also seem to imply some repulsive force at work.

Again, some gases, when compressed with great force, have their molecules forced so near that they become liquid; and in this condition they are seen to cohere and form drops, thus shewing that they are not destitute of attractive force. The natural conclusion from these and other observed facts is, that among the molecules of all bodies there are two opposing forces at work—an attractive force, and a repulsive force—that when attraction considerably predominates over repulsion, a solid body is the result; when there is almost a balance of the two forces, we have a liquid; and when the repulsive force has the upper hand, we have a gas. Many substances are seen to assume all three forms in turn. Liquid water turns at one time into solid ice, at another into vapour or steam. Greater extremes of cold and heat have the same effects on mercury. Several gases, by applying great pressure and cold, have been rendered liquid, and one at least even solid; and thus it becomes probable that all substances are capable of existing in any one of the three states under certain conditions.

From the fact that the increase of heat regularly increases the energy of repulsion, heat and the repulsive force may be considered one and the same thing. The subject of HEAT will be more fully considered under a separate head.

In solids, the cohesion is exerted in such a way as not only to keep the atoms from separating, but also to retain them in the same relative position; in liquids, on the contrary, the atoms, while still kept from separating, are allowed to move or slide freely upon one another in all directions. This free motion of the molecules upon one

another, rather than want of cohesion, is the grand characteristic of liquids as well as gases; it is one of the causes of drops being spherical. Differences of cohesion give rise to such distinctive qualities of bodies as the following:

Hardness.—This quality depends not so much upon the force with which the particles resist separation, as upon their resisting displacement or alteration of relative position. Softness implies the opposite. Hardness is tested by one body scratching another. It does not correspond with density. Thus, glass scratches gold, and even platinum. Steel has its hardness modified by tempering.—*Malleability* is a distinguishing quality of some metals, and means the capability of being extended into thin plates or leaves by hammering. It depends upon the union of softness and tenacity; the particles shift their position without separating. The most malleable metal is gold.—*Ductility* is the property by which a metal admits of being drawn into wire. The most malleable metals are not the most ductile. Iron is much more ductile than tin or lead, though not so malleable. The most ductile metal is platinum.—*Tenacity* expresses the quality by which a body resists being torn asunder, and depends upon the intensity of the cohesive force. It is not the opposite of *brittleness.* Brittleness is associated with hardness and unyieldingness, except within narrow limits. Glass is brittle—that is, is easily broken by bending or crushing—but a glass rod will sustain a great weight without being *torn* asunder. Thus it is both brittle and tenacious. The most tenacious of all substances is steel.

Adhesion, or, as it is sometimes called, heterogeneous cohesion, is the term applied to the attraction which makes two different substances stick to one another by their surfaces. Cohesion acts between the particles of the same kind of substance; adhesion, between dissimilar kinds of matter. Though the same force probably causes both, yet the effects are so different that it is convenient to consider them separately, and give them different names.

Adhesion between solids.—Particles of dust on an upright pane of glass, chalk-marks on a wall, sealing-wax on paper, cement, are all instances of adhesion between substances of different kinds. Adhesion between surfaces is the chief cause of friction, and unctuous substances are interposed to prevent it.

Adhesion of liquids to solids takes place much more readily than that of solids to solids, because in the case of a liquid and a solid the surfaces come into more complete contact. When the hand or a rod of metal is dipped into water, a film of the water adheres to the surface, and is borne up against its own weight; nor can any force shake it all off. Plunge a bit of gold, or silver, or lead, into mercury, and a portion of the mercury will in like manner adhere. Wherever we have *wetting*, we have a case of adhesion of a liquid to a solid. It is the cause that in pouring water over the edge of a vessel, the water is apt to run down the side of the vessel rather than fall perpendicularly.

But liquids do not always wet solids, or adhere to them. A rod coated with grease, or the wing of a water-fowl, remains dry when plunged in water. Mercury does not adhere to a porcelain cup, or to a rod of iron or platinum. The explanation is simple. There is in every case an attraction between the solid surface and the liquid, but it is opposed by the attraction of the particles of the liquid for one another, and there can be actual adhesion only when the former prevails over the other.

Capillary attraction is only a particular effect of adhesion. A tube with a small bore, like a hair, is called a capillary tube, from *capilla*, the Latin word for a hair. If the end of such a glass tube is dipped in water, the water is seen to rise in the tube above the level of the rest of the surface, as in fig. 1. In a series of tubes of different diameters, the liquid ascends highest in the smallest; or the heights are inversely as the diameters. Water will be seen to rise in a similar way between two glass plates placed as in fig. 3, with two of the upright edges touching, and the other two slightly apart. The sustained film rises higher as the plates approach, assuming the form of a particular curve. The fluid rises also slightly on the outside of the tubes and plates, and the surface of the sustained column within the tube is seen to be hollow like a cup.

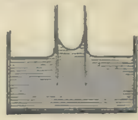


Fig. 1.

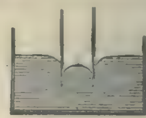


Fig. 2.

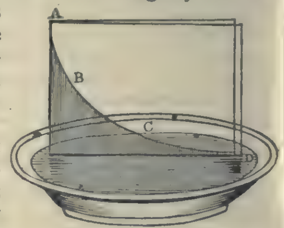


Fig. 3.

But liquids do not always ascend in narrow tubes or spaces; it is only when they wet the solid substance that they do so. If a greasy glass tube is dipped in water; or, still better, if a clean glass tube is dipped in mercury, the liquid inside, instead of rising, sinks below the general level; the surface of the column, too, becomes convex instead of concave, as represented in fig. 2.

The rise or the depression depends upon the adjustment between the forces of adhesion and cohesion, as in the case of wetting. When the liquid wets the tube, the particles next its surface have part of their weight taken away or supported by adhesion, and thus a longer column is required to balance the pressure of the rest of the fluid. In cases where the cohesive attraction of the liquid particles within the tube for one another is too strong to permit them to adhere to its surface, that cohesion tends to draw them away from it, and downwards; while the tube prevents them from receiving the support they would have from the liquid particles around them, if it were not there.

Capillary attraction is exemplified in many familiar appearances, and plays an important part in nature. If a piece of sponge or a lump of sugar be placed so that its lower corner touches the water, the fluid will rise up and wet the whole mass. In the same manner, the wick of a lamp will carry up the oil to supply the flame, though the flame is several inches above the level of the oil. If one end of a towel happens to be left in a

basin of water, while the other hangs over below the level of the water, the basin will be emptied of its contents; and, on the same principle, when a dry wedge of wood is driven into the crevice of a rock, and afterwards moistened with water, it will absorb the water, swell, and sometimes split the rock.

Endosmose or *Osmose.*—Connected with capillary attraction is *endosmose.* If two liquids be separated by a piece of ox-bladder, the one below the membrane being pure water, the other above being a solution, say of sugar, the water will pass through the membrane against gravity, and raise the solution above its former level. A smaller portion of the solution finds its way into the water. This remarkable phenomenon is known as *endosmose* and *exosmose,* or simply as *osmose.* It is not yet fully understood, but is believed to play a part in the passage of the fluids through the membranes of living animals and plants.

Adhesion between Solids and Gases.—In making barometers, it is found that air adheres so firmly to the surface of the glass, that the mercury must be boiled in the tube before it can be expelled. Some porous solids, such as charcoal, absorb air and other gases to an amount many times their own bulk, the force of adhesion condensing the gases on the surface of their molecules.

Chemical attraction is a force whose effects are of a different kind from those of cohesion. If we divide a piece of marble by breaking it into parts, however small, each part is still marble. But the chemist takes it to pieces in a different way. Out of a piece of marble he will produce three distinct substances, altogether unlike the original body—a metal not unlike silver, a black body called carbon, and a gas resembling air. Most of the substances of which our earth is made up are thus composed of two or more different substances or elements. Such unions are chemical unions; the ultimate particles that join to form them are called *atoms;* and the force that binds them, *atomic* force, or *chemical attraction.* The investigation of changes that thus alter the constitution of bodies, belongs to the science of CHEMISTRY.

MOTION AND FORCES.

Motion is change of place, and its opposite is rest. Motion in any one body has always reference to the place of other bodies, and various distinctive terms are used indicative of this reference. A man sitting on the deck of a ship has a *common* motion with it; if walking on the deck, he has *relative* motion to the vessel. *Absolute* motion means change of place with respect to space itself. But we have no means of marking a fixed point in space, and therefore can never observe such a motion; we know only relative motions. As little do we know of absolute rest. The earth is in constant rotation and also revolution round the sun; and the sun himself is in motion, we know not whither. Motion, and not rest, is the great law of the universe.

Velocity, or speed of motion, is measured by the space passed over in a given unit of time; as when we say that a man walks three miles an hour; or that sound travels 1120 feet in a second. The velocity is *uniform,* when equal spaces are always passed over in equal times; it is *accelerated,* when gradually increased, and *retarded,* when gradually diminished. If the increase or diminution is equal in equal times, the motion is said to be *uniformly accelerated* or *uniformly retarded. Force* is any agency that produces or tends to produce motion in a body, or to change or stop its motion; when the body is not free to move, the force exerts a *pressure.* Force and pressure are often used indifferently. The amount of a pressure is measured by the weight it can support, which is stated in pounds, ounces, &c. A force causing motion is measured by the quantity of motion or *momentum* it can communicate in a given time. Momentum does not depend upon velocity alone. Of two balls moving at the same rate, but the one having twice the mass of the other, the larger has just twice the momentum. Momentum, then, is made up of velocity and quantity of matter taken together. To get the comparative momenta of two bodies in numbers, we multiply the weight of each by its velocity.

LAWS OF MOTION.

The leading truths respecting the movements of bodies have been summed up in the shape of a few axioms, or propositions, which were first put into shape by Newton under the name of *Laws of Motion.* We shall give them as laid down by Newton, and then follow them up with observations on each.

1st. Every body continues in its state of rest, or of uniform motion in a straight line, except in so far as it may be compelled to change that state by forces impressed upon it.

2d. Change of motion is proportional to the impressed force, and takes place in the direction of the straight line in which the force is impressed.

3d. To every action there is always an equal and contrary reaction; or the actions of two bodies upon each other are always equal, and oppositely directed.

FIRST LAW.

This law is little else than a definition of the property of Inertia or Inactivity. There are three things to be attended to in this law—namely, the *persistency* of matter, both in rest and motion, when not acted upon by external agency; the *uniform* velocity; and the *straight* direction of motion when once begun and left to itself. The first has been already illustrated under the head of Inertia; and when we say that unobstructed motion is naturally *uniform,* we are only repeating in a different form the same truth.

A little reflection brings out the truth of the third point—namely, that motion is naturally *straight.* If a ball projected forward is seen to bend to the right or the left, we infer at once that something interfered with it. That it bends downwards, we know to be owing to the attraction of the earth. Motion therefore requires force to bend it.

SECOND LAW.

That every change of motion is proportional to the force that produces it, is involved in the way of measuring force, which is by the quantity of motion it gives or takes away. As to the *direction* of the resulting motion, the law requires careful explanation. When the body is previously at rest, it is self-evident that, if unobstructed, it will follow the direction of the force that begins to act

upon it; but if it is already in motion in one direction, and a force then comes to act upon it in another direction, it is not so clear what course it will take. To determine the path or line in which a body will move when thus acted upon by more forces than one, is one of the fundamental problems of the science of mechanics. It is usually treated under the title of the

Composition and Resolution of Motion.

Let the ball, B, be moving along the line AC with a velocity that would carry it from B to C in two seconds, and when at B let it receive a blow that would carry it from B to E in the same time; the question is: How will the ball now move? This is best understood

Fig. 4.

by supposing it placed, not on a plane surface, but in a groove in the upper side of a movable bar lying on a table. The ball being then set rolling at the same rate as before along a groove in the bar AC, let the bar be made at the same time to slide across the table, keeping parallel to itself, and carrying the ball along with it, so as to arrive at the position ED in two seconds. The common motion of the bar and the ball will not in any way interfere with the motion of the ball in the groove, any more than the common motion of a ship and a man on board of it interferes with the man in walking across the deck. The ball will be at the end of the groove at the end of the two seconds, just as if the bar had been at rest; it will, therefore, as a result of the two movements, be found at the point D.

If the position of the ball on the table is observed at the intermediate points, it will be found to describe a straight line from B to D; for since we have supposed both motions uniform, the bar will, at the end of the first second, be in the position *gf*, midway between BC and ED, and the ball will at the same instant be half-way from *g* to *f*, at *k*; and it can be proved that *k* is in a straight line between B and D. The same could be shewn as to any intermediate stage.—When both motions are not uniform, the body moves in a curve, as will be seen in speaking of projectiles.

The movable groove is introduced to make the effect of two movements conjoined more readily conceived; to shew palpably, as it were, that a body may be moving in two directions at one and the same time. But if it receive the second impulse by a blow while rolling freely on the table, it will still arrive at D by the same path.

In any case, then, when two impulses act upon a body, if we draw two straight lines, AB and AC, in the directions of the two impulses, and make the lengths AD and AE in proportion to the velocities that the forces would give to the body if acting separately; then if we draw EF and DF parallel to AD and AE, and join AF, this line, which is called the *diagonal*, gives the direction that the body will move

Fig. 5.

in, and also its velocity. A figure thus formed represents both the velocities and the impulsive forces that produce them, and is called the *parallelogram of velocities*, or the *parallelogram of forces*. AD and AE are called the *components*, and AF the *resultant*.

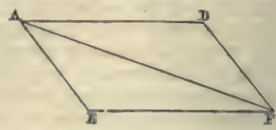


Fig. 6.

In figs. 4 and 5, the forces are represented as acting at right angles to one another; but the angle may vary, as in figs. 6 and 7, and the learner should observe the effect on the resultants as he draws parallelograms with angles still narrower or still wider.

Fig. 7.

We arrive at a similar result if, instead of motions, we consider a set of forces acting against one another so as to prevent motion. When forces thus balance one another, they are said to be in *equilibrium;* and the investigation of such cases forms the part of Mechanics called *Statics* (from a Greek word signifying 'to stand'), while the consideration of force producing motion belongs to *Dynamics* (from the Greek word for 'power').

Two strings fastened to the ring R, and drawn in opposite directions by equal forces, F and F′, will keep the ring at rest, and the forces are then in equilibrium.

Fig. 8.

Now, it is evident that for one of the two forces we could substitute two other forces, as in fig. 9, pulling in the directions R*f*, R*f′*, which, if

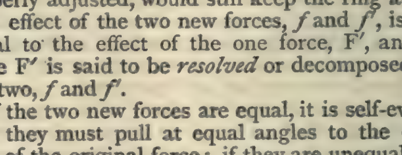


Fig. 9.

properly adjusted, would still keep the ring at rest. The effect of the two new forces, *f* and *f′*, is thus equal to the effect of the one force, F′, and the force F′ is said to be *resolved* or decomposed into the two, *f* and *f′*.

If the two new forces are equal, it is self-evident that they must pull at equal angles to the direction of the original force; if they are unequal, that the greater must be more nearly in that direction than the other, as is represented in the figure. The exact proportion of the two to each other and to the one original force, may be determined thus: Supposing that F′ was a force of six pounds, set off a length of six parts from R to *a*, and then draw *ab*, *ac* parallel to R*f* and R*f′*. We have then a parallelogram of forces. R*c* represents the magnitude of the force *f*, R*b* that of the force *f′*, and R*a* is the resultant, and represents the amount of their combined effect in the direction of RF′. The truth of this may be proved both by mathematical demonstration and by actual

trial. The experimental proof is better suited to our present purpose, and any one may make it for himself. Over two pulleys, A and B, let a string be passed, having two weights, w, w', attached, one at each end, with a small ring in

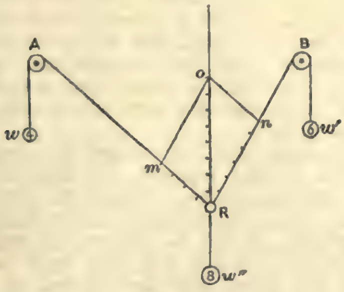


Fig. 10.

the middle, and to this ring let another weight, less than the sum of the other two, be suspended. This third weight will pull down the ring R a certain way, and at last take up a position of rest; the three forces will be in equilibrium. If the weights w and w' are equal, it is evident that w'' will hang midway between the pulleys. But we suppose them unequal; and then every one's experience will tell him that the ring will be drawn nearer to the greater. Suppose $w = 4$ pounds, $w' = 6$, and $w'' = 8$; draw on paper the exact figure made by the strings; take any small unit of length, and set off 4 such units from R to m, and 6 from R to n; through m and n draw mo and no parallel to Rn and Rm, and join Ro. It will be found that Ro is in the same straight line with Rw'', and also that it contains 8 units of length.

As ba in fig. 9 is equal to Rc, and in the same direction, the two component forces and their resultant are represented by the three sides of the triangle Rba; and the resolution of forces is thus often represented by the half of the parallelogram of forces, to save drawing the whole.

The following is an example of the resolution of forces:

Let TP be a ship, SL its sail, WA the direction of the wind, and let the length of WA represent the force of the wind. WA can be resolved into AB perpendicular to the sail, and BW parallel to

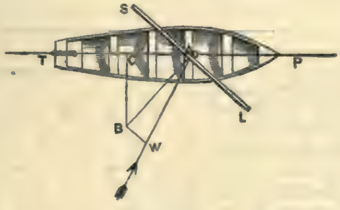


Fig. 11.

it, the latter of which has no effect in pressing on the sail; therefore AB is the effective pressure on the sail. Were the vessel round, it would move in the direction BA. Let BA be resolved into CA and BC, the former, CA, acting in the direction of the keel or length of the vessel, or in the direction CA, and the latter perpendicular to it, or in the direction of the breadth. The former pressure, CA, is the only pressure that moves the vessel forward, the other, BC, makes it move sideways. From the form of the vessel, however, this latter force, BC, produces comparatively little lateral motion; any that it does occasion is called *leeway*. —By a similar double resolution, we may represent how much of the actual force of the wind is effective in turning round the arms of a wind-mill.

THIRD LAW.

If a man standing in a boat attempt to push off another boat of the same size that is alongside, both boats will recede equally from each other; if he pull the other boat towards him, his own boat advances half-way to meet it. A magnet draws a piece of iron towards it; but the magnet is also drawn towards the iron, as is seen when they are both suspended so as to move freely. In all these cases, we see that the body that we consider as acting upon the other, is itself acted upon in turn, and in the opposite direction: this is what is meant by *reaction*.

In saying that the action and reaction are *equal*, it is meant that the momentum produced or destroyed on both sides is the same. If the magnet and the piece of iron above spoken of are of the same weight, they move to meet each other with equal velocities, for thus only can the momentum be the same in both cases. If the magnet is three times the weight of the piece of iron, the iron must move with three times the velocity of the magnet in order to have equal moving force; and so it is found to do.

In the last instance, both motions would still be visible. But let a boat of a ton weight be pushed away from the side of a ship of a thousand tons' weight, and then only one seems to move; for while the boat moves off a yard, the ship recedes only the thousandth part of a yard, which it would require minute observation and measurement to render apparent. From this we can pass to the extreme case of a boat pushed off from shore. Where is the evidence of reaction here? We see none, it is true; still, the consideration of the cases already adduced, and of a thousand similar, lead us irresistibly to believe that the shore, if it is free to move, must recede from the boat. We cannot help believing, then, that when a stone falls—in other words, when the earth draws a stone towards it—the earth is itself drawn, or falls, towards the stone.

COMMON MOTION.

When a system of bodies has, from any cause, received a common motion, their positions, with regard to one another, remain unaffected by it, and in considering their relative motions, we may leave their common motion out of account; everything is as if the system were at rest. This arises from the property of inertia, as already expounded. When a ship is going steadily, all things go on in the cabin as in a room. On deck, a ball thrown upwards comes down in the same spot; the deck has not slipped away from under it. The *motal inertia* of the ball carried it on while in the air with the motion it had acquired from the ship.

The feats of equestrians depend upon this law of common motion. Riding at full speed, they throw up balls, which return into the hand. The

rider springs right up from the saddle, and alights on it again without falling behind the horse. Additional illustrations of this law will be found under METEOROLOGY and PHYSICAL GEOGRAPHY.

TERRESTRIAL GRAVITY.

It is a law, as we have seen, wide as the universe, that every particle of matter acts upon every other particle by the force known as gravitation, which draws them one towards another. We are now to consider the laws of this force, and explain the more important phenomena it gives rise to.

The attraction of gravitation is always in proportion to the mass of the attracting body. This will be readily admitted. A force is exerted by each atom, and the more atoms the more force. It is not the volume or bulk of the body, but its quantity of matter, that decides its effect. Gravitation, again, acts at all distances, but with diminished effect as the distance increases. The decrease, however, does not go on in a simple proportion; twice the distance does not give simply half the attraction. If, at the distance of a foot, the force of attraction between two bodies were a pound, at the distance of 2 feet, it would be $\frac{1}{4}$ of a pound; at 3 feet, $\frac{1}{9}$th of a pound; at 4 feet, $\frac{1}{16}$th of a pound. This is expressed by saying that attraction varies inversely as the squares of the distances between the bodies.

The distance between two mutually attracting globes is measured from centre to centre. The attraction of the earth, then, on a body at its surface is exerted at the distance of about 4000 miles, which is the length of its *semi-diameter;* at the height of 4000 miles above the surface, or at the distance of two semi-diameters from the centre, the attraction is reduced to one-fourth. The moon being at the distance of sixty semi-diameters, the earth draws it with a force which is only a 3600th part of what it would be, were the moon at the earth's surface. It belongs to astronomy to treat of gravitation as ruling the planetary motions; we have here to speak of the phenomena it produces on bodies at or near the earth's surface.

The attraction of the earth for bodies on its surface is so strong, owing to its overwhelming mass, that it overpowers their attraction for one another, and renders it in most cases inappreciable. But a plumb-line suspended near a large mountain is sensibly drawn from the perpendicular; and by a delicate instrument, called the torsion-balance, the action of a large ball upon a small one has been measured. The *weight* or gravity of a body is another name for the force with which it is drawn towards the earth.

Falling Bodies.

Perhaps nothing explains more phenomena than the complete understanding of what takes place when a body falls; for half the motions in the world are caused, directly or indirectly, by falling. Falling is the best instance of a *uniformly accelerated* motion. Gravity not only puts a body in motion, but *continues* to act on it with equal force after it is in motion, and thus is uniformly adding to its speed. This acceleration is seen in every body dropped from a height through the air; and no less in a rock rolling down a declivity, which continually gathers force as it descends, till its energy is sufficient to shatter itself and everything it encounters to pieces.

All bodies, heavy and light, would fall equally fast if the resistance of the air were removed. A ball of lead two pounds' weight does not fall faster than a ball of one pound. A gold leaf, however, will fall considerably slower than the same gold in a solid state, because it exposes much more surface to the air. That this is the cause of the difference, is shewn by an experiment with the air-pump, in which a guinea and a feather are dropped in a vacuum, and fall to the bottom together.

It has been well ascertained by observation, that when a body begins to fall from a state of rest, it descends 16 feet 1 inch in the first second of time. (This measurement varies slightly with the latitude, as will be afterwards explained.) Suppose that no fall had ever been observed beyond that point, and that we had to find by reasoning what the body would do during the next second. The first consideration is, How far would the body fall, if gravity were to cease?—in other words, What velocity has it acquired? It would not be unnatural to say 16 feet (we omit the 1 inch), since that is the space it fell in the second that is ended; but reflection shews that this cannot be the case. During the first half of the second, it made very little way, and the greater part of the distance was passed over in the last half; 16 feet expresses the mean velocity, or the velocity it had at the middle of the second, and at the end it must have been moving with a velocity just double the mean. The velocity acquired, then, at the end of the first second is 32 feet; and if gravity were to cease, it would, by the law of inertia, move over 32 feet in the next second. But gravity still acting, will make it fall another 16 feet in addition to the 32, or 48 feet in all; and will create as much velocity in addition as it created in the first second, so that if it were to cease at the end of the second second, the body would move 64 feet in the third second. Thus, during the second second, the body will fall through three spaces of 16 feet, and at the end of it will have its velocity double of what it was at the end of the first second. The whole space fallen during the two seconds will thus be four spaces of 16 feet.

We arrive at this result by reasoning, and observation proves it correct. Without giving the steps of the investigation for the succeeding spaces of time, the results may be exhibited in the following table:

Number of Seconds.	1	2	3	4	5	&c.
Velocities at the end of number of seconds in spaces of 16 feet,	2	4	6	8	10	&c.
Spaces fallen through during each successive second,	1	3	5	7	9	&c.
Spaces counted from beginning of fall,	1	4	9	16	25	&c.

For example: The third column, headed 3 (seconds), informs us that at the end of 3 seconds a falling body is moving (for the instant) at the rate of 6 spaces of 16 feet—that is, of 96 feet—a second; that during the third second it falls 5

spaces, or 80 feet; and that the whole distance fallen during all the three seconds is 9 spaces, or 144 feet.

The distances that bodies fall, then, do not increase simply as the times, but as the *squares* of the times. To find, therefore, how far a body will fall in any number of seconds, multiply the number of seconds by itself, and that product by 16. Thus, in 7 seconds, a body will fall $7 \times 7 \times 16 = 784$ feet. The height of a precipice might be roughly measured in this way, by observing how many seconds a stone takes to reach the bottom.

As a body in descending to the earth receives increasing accessions to its velocity during every successive second, so, when a body is projected upwards from the surface of the earth, its velocity decreases in the same proportion till it comes to a state of momentary rest, when it instantly begins to descend with a gradually increasing velocity, which at any point in the descent is equal to its velocity at the same point when ascending. In this calculation, however, we omit the influence of the atmosphere.

Projectiles.

Any heavy body launched or *projected* into the air with an impulse, is a projectile; and to investigate the motions of such bodies forms a distinct branch of the science of motion.

Suppose a cannon-ball fired from the top of a tower, whose height is represented by the line A4′, in the direction of the horizontal line AB. The

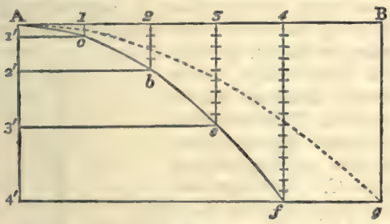


Fig. 12.

force of the gunpowder ceases to act as the ball leaves the cannon, and the ball retains a uniform velocity which would carry it over equal spaces in equal times. Let A1 be the space the ball would describe in a second if acted on only by the projectile force, and set off a number of equal spaces along AB. Now, from the moment the ball leaves the mouth of the cannon, it is acted on by gravity; and while moving in the direction of AB, also falls; so that at the end of a second it must be 16 feet lower than it would have been if gravity had not acted—that is, if we take the perpendicular line 1*c* to represent 16 feet, the ball will at the end of the first second be at *c*. The horizontal motion being uniform, the ball at the end of the second second would be at 2, or twice as far towards B; but its downward accelerated motion has in the meantime dragged it down through three spaces more—in all four spaces—of 16 feet below the horizontal line. Making 2*b*, therefore, equal to four times 1*c*, gives *b* as the point where the ball will be at the end of the second second. By similar reasoning, if 3*e* is made equal to nine times 1*c*, 4*f* equal to 16 times 1*c*, &c. according to the law of accelerated motion; *e*, *f*, &c. will be the points at which the ball will be found at the end of the third, fourth, &c. seconds. The resultant of these two dissimilar motions, the one uniform, and the other uniformly accelerated, is a curve of the kind called a parabola, as represented in the figure.

From the above investigation, this remarkable consequence follows: that a body projected horizontally from a height above a level plane, comes to the ground as soon as if it were let fall perpendicularly. The ball reaches *f* in the same time that it would fall from A to 4′. A greater velocity of projection would make it take a wider flight; but its horizontal motion does not interfere with its downward motion, and at the end of four seconds it must be at some point in the same horizontal line—at *g*, for example. Two balls, then, projected horizontally from the same height above a level plane, though the one may range only a mile, and the other two miles, will reach the ground at the same time.

Projectiles are mostly thrown, not horizontally, but in an oblique direction. We arrive, however, at the path described in the same way as in the last case.

The laws above arrived at respecting projectiles are strictly true only on the supposition that the movements are made in empty space. But every projectile has to encounter the resistance of the air; and that resistance becomes so great when the velocity is very high, that in the practice of gunnery the theory is of little value. With a small velocity, however, a body thrown through the air describes a path not differing much from a parabola.

Since the distance of the flight, and the width of the curve described by a projectile, increase with its initial velocity, we can conceive the velocity increased until the curve became as large as that of the earth itself. If this were the case, the projectile, instead of falling, would, if the resistance of the air were removed, continue to go round and round the earth for ever. We thus arrive at the idea of planetary motion. The moon, for instance, is constantly falling towards the earth, like a cannon-ball shot horizontally; but the projectile velocity which it had from the beginning, and which, as it moves in empty space, it retains undiminished, is sufficient to carry it clear round in the curve called its orbit.

Centre of Gravity.

The centre of gravity of a body is that point about which the body balances itself in all positions. When a rod of uniform thickness and density is suspended by its middle point, it remains at rest. There is as much matter on the one side as the other; the atoms balance one another in pairs; and it is as if the whole were collected at the point of suspension. The centre of gravity of such a rod is the central point at its middle part; and if the substance of the rod is pierced, and this central point rested on a fine needle, the rod will remain immovable in whatever position it is put.

Whenever bodies are regularly shaped, and of uniform density, their centres of gravity may be found by mathematical measurement, as in the case of the rod. Thus the centre of gravity of a globe is evidently in its middle point, or centre of dimension.

The position of the centre of gravity in a triangular-shaped body is not so obvious. It is thus found. If ABC represent the surface of a thin triangular board, we may suppose it composed of a number of small rods laid side by side, the line AB representing the first, and the others gradually diminishing in length to the top. Now, the centre of gravity of the rod AB is in its middle point D; and if we join the points D and C, the line will pass through the centres of gravity of all the other rods; because it is a property of a line drawn from the top of a triangle to the middle of the opposite side, to bisect or pass through the middle of all lines in the triangle parallel to that side. The centre of gravity of the whole, therefore, must lie somewhere in the line CD. Again, by conceiving the triangle made up of rods parallel to the side CB, and drawing a line from A to the middle point E, we see that the centre of gravity must, in like manner, lie somewhere in the line AE. Now, since it lies also in CD, it can lie only where the two cross—namely, at *g*. We have thus found the centre of gravity of the surface, as it were; and if the board have any sensible thickness, its actual centre of gravity will lie behind *g*, at the distance of half the thickness. It is one of the properties of the triangle, that the line D*g*, determined as above, is always one-third of the whole line DC; thus the centre of gravity of a triangle is readily found.

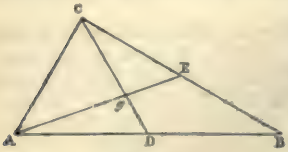


Fig. 13.

When two balls are connected by an inflexible rod, they form but one body, and the common centre of gravity is not situated in either, but between them in the rod joining their centres. If the balls are equal in mass, it will evidently be in the middle of the rod; but if they are unequal, the point where they balance each other is found to lie nearer to the larger mass. See MECHANICS.

The centre of gravity has always a tendency to seek the lowest point, and this enables us readily to find the centre of gravity of an irregular body. For example, let a painter's pallet be suspended from the thumb-hole, as in the figure; we know that the centre of gravity must be perpendicularly below the point of suspension, and if we allow a plumb-line or a straight rod to hang down from that point in front of the pallet, and mark the line under it, the centre of gravity must be on that line. Next, suspend the pallet from any other point, D, and apply the plummet as before, and another line is found also containing the centre of gravity, which must therefore be where the lines cross. If a third line of direction is tried, it will be found to pass through the same point.

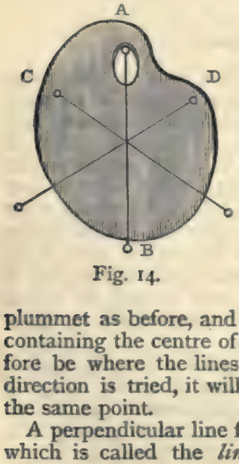


Fig. 14.

A perpendicular line from the centre of gravity, which is called the *line of direction*, must fall within the base of any object resting on the ground, otherwise it will fall. A structure may overhang its base within certain limits. In A (fig. 15) the line of direction falls within the base,

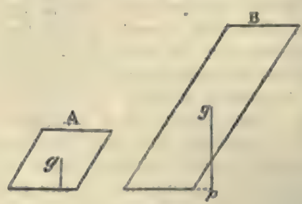


Fig. 15.

so that the centre is still supported, and would have to *rise* before the body could tumble; in B, the centre is unsupported, and moves in a descending curve from the first. The instability here arises from the *height* of the object, for the slope and base are the same in both.

This explains why vehicles when loaded high, or made *top-heavy*, are so easily upset.

The Pendulum.

Any heavy body, such as a ball, suspended by a string or rod, so as to swing freely, constitutes a pendulum. Swinging is no less an effect of gravity than falling; and from the importance of the pendulum, as a measurer of time, the phenomenon deserves attentive study.

In the accompanying cut, a pendulum of the most common construction is represented, suspended at A. When the ball or bob, C, is drawn to one side, as to D, gravity urges it downwards, while the tension of the rod draws it towards A. The composition of the two forces makes it describe a descending curve to C. But the ball does not stop here; it goes on, by the law of inertia, in the ascending curve CD′, until gravity destroys its acquired motion. If friction and the resistance of the air did not interfere, the ball would reach the same elevation as it started from. But these causes gradually render the ascent less and less, and at last bring the pendulum, when it has no maintaining power, to a state of rest.

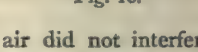


Fig. 16.

One sweep of a pendulum from D to D′ is called an *oscillation*. The most remarkable property of the oscillations of the pendulum, and that on which its use as a regulator of movement depends, is that, whether long or short, they are all performed in very nearly the same time. If we observe the vibrations of any body set swinging, we find that, though the arc it describes is continually diminishing, there is no sensible shortening of the time in which the single sweeps are accomplished. As the journey becomes less, so does the velocity. Galileo is said to have been the first that distinctly noted and investigated this important fact. It is easy to see, in a general way, that the wider the sweep of the ball, the steeper is its descent at the beginning; and that the greater velocity thus acquired must more or less compensate for the longer journey; but the mathematical proof that

the times are thus exactly equalised would be out of place here.

It is only short oscillations that are thus *isochronous*, as it is called; when the arcs are large, the steepness does not increase in exact proportion to the length, and therefore the isochronism is not perfect. Accordingly, pendulums are made to swing in short arcs; and then, though no contrivance could make the extent of the oscillations exactly uniform, the times are virtually equal.

But though the time of oscillation is not affected by the largeness of the arc, it is by the length of the pendulum itself. Long pendulums vibrate more slowly than short ones. Though the balls B and D in the fig. have the same amplitude of vibration, or go over corresponding arcs, the journey of the one is longer than that of the other. But the steepness of descent, or inclination of the path, is the same in both; therefore B must take longer time to perform its journey than D. We must not, however, conclude that when the length of the arc, or, which is the same thing, of the pendulum, is doubled, the time of oscillation is also doubled. The motion of the pendulum is an accelerated motion; and, as in all other uniformly accelerated motions, the spaces described are as the squares of the times. To give double the time of vibration, then, requires the pendulum to be four times as long; treble the time, nine times as long; and so on. A pendulum of a little more than 39 inches beats seconds, and one of one-fourth that length beats half-seconds.

Fig. 17.

When we say that the seconds pendulum is always of the same length, we must be understood to speak of the same place. In different places, its length varies. At the equator, owing to the shape of the earth, we are thirteen miles further from the centre than at the poles; the force of gravity is therefore less, and thus the seconds pendulum must be somewhat shorter at the equator, and grow gradually longer as the latitude increases.

The length of a pendulum is measured from the point of suspension, not to the bottom, or even the centre of the ball, but to a point called the *centre of oscillation*, where the whole mass of the swinging body—rod and ball together—may be supposed concentrated. The determination of this point is a matter of some difficulty. The use of the pendulum in regulating clocks is considered in the number on HOROLOGY.

CENTRIFUGAL FORCE AND CIRCULAR MOTION.

Motion in a circle, or in any other curve, is something constrained. When we make a ball whirl round rapidly at the end of a cord, we feel the cord stretched with a sensible force; the ball is pulling outwards, and the hand is pulling inwards. The outward pull of the ball is called the *centrifugal*, or centre-flying force; the inward pull of the hand, the *centripetal*, or centre-seeking force. The tension of the cord is the measure of both forces.

When a body, constrained to move in a circle, is released from the restraint, what is the result? Suppose the ball B retained by the cord AB, and moving in the direction CEG, &c.; if relieved from the restraint of the cord, it does not fly directly away from the centre, in the line AB prolonged. It has still its onward motion in the direction of the curve, and the only effect of the release from the centripetal force is, that that motion ceases to be bent, and goes on straight in the direction it had at the instant. Now, at any point in a circle, the direction of the curve is that of a straight line drawn through the point at right angles to the diameter. Such a straight line is called a *tangent;* and thus motion in a circle, when released from the constraining force, becomes motion in the tangent, or flies off at a tangent. At C, for instance, the direction of the ball, when set free, would be CD; at I it would be IK.

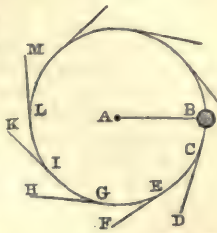


Fig. 18.

The tendency to fly off from the centre and at a tangent, is exemplified in a multitude of phenomena. A stone let go from a sling is the most familiar instance. When a vessel with water in it is rapidly turned round like a horizontal wheel, the water recedes from the centre, and rises up round the sides.

In equestrian performances in a circus, both rider and horse incline their bodies inwards; they are leaning against a force which is impelling them outwards, and which thus sustains a part of their weight. A skater must do the same in describing a curve. If a round ball of soft clay be turned rapidly on a spindle, it ceases to be perfectly round in all directions: it bulges out at the middle and shortens in the direction of the spindle. This has happened to our earth; and to a still greater degree to Jupiter and Saturn, which have a more rapid rotation on their axes.

The centrifugal force of a body moving in a circle increases as the mass of the body, and as the square of the velocity. It is calculated that if the rotation of the earth were seventeen times faster than it is, centrifugal force at the equator would be equal to gravity; in other words, all bodies would be completely without weight, and a little increase of velocity would throw them off, to circle round like small satellites.

HEAT.

To account for the appearances presented by matter in its several forms of solid, liquid, and gas, we have seen it necessary (p. 195) to assume that there is a *repulsive* force at work among its molecules, counteracting and modifying the attractive forces. This repulsive force would seem to be identical with heat. Heat expands bodies; it overcomes the cohesion of their particles, converting solids into liquids, and liquids into gases; without it, there would be only one form of matter, the solid, and all life would cease on the earth.

As to the nature of heat, there have been two theories. The prevailing theory at one time was, that it was a distinct material substance, though imponderable; a subtle fluid stored up in the spaces between the atoms of the grosser kind of matter. The universal view now is, that *heat is a mode of motion*. When a lump of lead is allowed to drop from a considerable height upon a hard body, it is found to be sensibly heated. In this case the motion of the lead has been arrested, but not destroyed. *Motion, like every other form of energy, is as indestructible as matter itself;* it is only the form of it that has been changed.* The motion of the mass has been transferred to the atoms or molecules, which are made to move or vibrate to and fro, each by itself; and it is this movement of the atoms and molecules that affects the nerves with the sensation of heat. These molecular motions are, like the molecules themselves, far too minute for actual observation; so that we cannot say whether they are revolutions in an orbit, or oscillations backwards and forwards; but the assumption of a motion of some kind seems necessary to the explanation of the observed facts.

Perhaps no class of natural laws are more interesting in themselves, or more practically important, than the laws of heat. A knowledge of them is of direct application in every art and handicraft, as well as necessary for domestic economy and personal comfort. A full discussion of the subject would require a volume; it is only the most general facts that the limits of this tract permit to be stated.

EXPANSION.

As a rule, all bodies, whether solid, liquid, or gaseous, which are not decomposed by heat, are expanded by it. Solids expand least, gases most, and liquids—speaking generally—are intermediate between them in expansibility.

To illustrate the expansion of solids, a rod of iron may be taken, and its length and diameter exactly measured at the temperature of the air. If it be now raised to a red heat, it will be found to have suffered an increase in length, and to be too wide to fit an aperture through which it passed before. When allowed to cool to its original temperature, it will exactly recover its previous dimensions.

The expansion of liquids is familiarly illustrated by heating a glass flask filled with any liquid. The liquid rapidly expands, and manifests its expansion by running over. If a bladder three-fourths filled with air is held near a fire, it becomes quite stretched, and may be made to burst, thus illustrating the expansion of gases.

Nearly every solid and liquid has an expansibility peculiar to itself. Among solids, the metals are the most expansible bodies. Zinc expands most, platinum probably least among bodies of the metallic class. Glass, brick, porcelain, marble, and stone, have small expansibilities. If a rod of iron which measures 819 lines in length when as cold as melting ice, is made as hot as boiling water, it is found to measure 820 lines. Between the freezing and boiling points, then, iron increases $\frac{1}{819}$ of its length; for the same increase of heat, glass expands only $\frac{1}{1147}$ of its length.

Among liquids, we find those which are most volatile more expansible than others. Gases, unlike solids and liquids, have not specific expansibilities, but each undergoes almost the same amount of expansion for the addition of the same amount of heat.

When heated from 32° to 212°, mercury dilates $\frac{1}{55}$ of its bulk, and alcohol $\frac{1}{9}$; air or any other gas about $\frac{1}{3}$. An increase of 1° of temperature, therefore, increases a body of air by $\frac{1}{480}$ of its bulk.

The mechanical theory of heat, that is, the theory that it is a mode of motion, quite accounts for the phenomena of expansion. If heat consists of vibrations of the particles of matter, to increase it is to increase the rapidity and width of the vibrations. Thus the particles are made to urge one another farther apart, and the volume of the body is increased. Further, as the force of cohesion which opposes this separative tendency differs in different substances, we should expect the expansive effect of heat to be greater in one case than another; and this is what, in fact, happens. The liquid and gaseous forms of matter are readily explained as still further effects of these molecular motions. In solid bodies, we may conceive that the force of cohesion, while allowing to each molecule a power of vibration within certain limits, yet holds the orbits or paths of these vibrations together in fixed positions relatively to one another. But as the particles continue to be urged farther apart by fresh accessions of heat, cohesion becomes too weak to hold them in fixed positions; they are now at liberty to roll or glide around each other; in other words, the substance has melted or become liquid. If urged yet farther asunder, they get beyond the sphere of cohesion, and seek to fly away into space, and in this condition they constitute gas or vapour.

Water presents a singular irregularity in its expansions and contractions. If boiling water is taken, and allowed gradually to cool, it follows the general law, and goes on contracting until it is within a few degrees of freezing (at 39°); it then begins to dilate, and continues to do so till it come to 32°, the freezing-point. At the moment of becoming solid, it undergoes a sudden enlargement. It is this enlargement of freezing water that causes it to burst pipes and vessels in which it is confined; it is also the reason that ice is lighter than water, and floats on the surface. Ten cubic inches of ice weigh as much as nine cubic inches of water.

In laying the rails on a railway, and in all structures where metal is used, allowance must be made for the expansion and contraction of the metal by change of temperature. The practical mechanic avails himself of the law of expansion in putting on the tires or rings of wagon-wheels and iron hoops on vats. Being made a degree too small at first, the tire or hoop is heated to redness, and in this state driven on; it is then cooled with water, when it contracts, and draws the parts of the wheel or vessel together with an irresistible force.

THE THERMOMETER.

The thermometer is an instrument in which *temperature*—that is, *the intensity of heat*—is measured by the amount of expansion it produces.

* This is the doctrine embodied in the phrase, *The Conservation of Energy*, which will be further exemplified in treating of Light and Electricity.

The most convenient substances for the construction of thermometers are found to be mercury and alcohol, or spirit of wine. For ordinary temperatures, mercury is preferable; but when too much heat is withdrawn, it freezes or becomes solid, and therefore, for very low temperatures, alcohol is used, which cannot be congealed by any known cold. The mercury or alcohol is inclosed in a glass tube with a hollow bulb at one end, the other being closed. It is then graduated by first plunging it in melting ice, and marking on the glass, or on an ivory scale attached to it, the point at which the mercury comes to stand. This mark is the *freezing-point* of water, for water freezing and ice melting have the same temperature. The thermometer is next placed in boiling water, when the mercury rises to a certain height, and then continues steady. A second mark is here made, which is the *boiling-point*.

The space between these two points is then divided into a number of equal parts, called *degrees*, and parts of the same length are set off above and below the boiling and freezing points, as far as required.

In the thermometer used in this country, the space between the freezing and boiling points is divided into 180 equal parts, and we begin counting at 32° below the freezing-point. A cipher is placed there, and it is called the zero or nothing-point of the thermometer. The freezing-point of water thus comes to be marked by the number 32°, and the boiling-point, which is 180° higher, by 212°. In the thermometer chiefly used on the continent, the space between the freezing and boiling points of water is divided into 100 equal parts, and the graduation begins at the freezing-point, which is marked 0°, or zero. According to this thermometer, which is called the centigrade, water freezes at 0°, and boils at 100°.

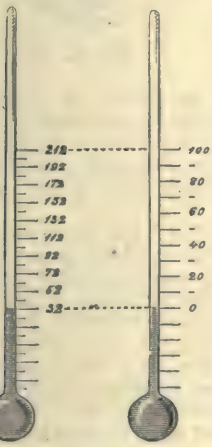


Fig. 19.

The centigrade thermometer is now much employed in scientific researches in this country. To prevent any confusion arising from its being mistaken for the thermometer first described, which is called, from its original maker, Fahrenheit's, or the Fahrenheit thermometer, the letter F is placed after temperatures indicated by his thermometer, and the letter C after those denoted by the centigrade.

From its zero-point each thermometer counts downwards as well as upwards; and to distinguish the degrees below zero from those above it, the former are distinguished by prefixing to them the minus sign —. Thus, mercury is said to freeze at − 40° F.; that is, at 40° below Fahrenheit's zero.

Another scale much used in Germany is that called Réaumur's, in which the freezing-point is marked 0°, and the boiling-point 80°. The degrees on this scale are thus larger than those of Fahrenheit, or even of the centigrade: 9° F. = 4° R. or 5° C.; and by means of these proportions, a temperature stated in one scale may be reduced to either of the others, care being taken to allow for Fahrenheit's scale commencing, not at the freezing-point, as the others do, but 32° below it.

Fahrenheit chose the temperature of 32° below freezing as the zero-point of his scale, because it was the lowest that had then been observed, and was considered to indicate the complete absence of heat; but it is now known that there are natural temperatures at least 90° below this; and by artificial mixtures, a cold has been produced of −146° F.

SPECIFIC HEAT.

Different substances require different quantities of heat to raise them to the same temperature. This is expressed by saying that each possesses a *specific capacity* for heat, or, more shortly, a *specific heat*. The fact can be proved in a variety of ways. Thus, if we cause equal quantities of bodies which have all been raised to the same temperature, to melt ice, we shall find that a much greater weight of it will be melted by one body than by another. Thus, mercury at 212° will melt much less ice than an equal quantity of water at the same temperature will, for the mercury has much less heat to give out, so as to produce liquefaction, than the water has.

Specific heats are generally stated with reference to equal weights, rather than to equal measures, of bodies. Thus, a pound of water in rising to a given temperature, absorbs thirty times more heat than a pound of mercury in rising to the same temperature; so that the capacity of water for heat exceeds that of mercury thirty times; and if we call the specific heat of mercury 1, that of water will be 30.

The mechanical theory of heat affords a satisfactory explanation of this difference in bodies. Chemistry establishes that the atoms of different substances differ greatly in weight; an atom of oxygen, for example, has sixteen times the weight of an atom of hydrogen. Now, experiment seems to prove that when two substances are at the same temperature, the ultimate particles of both have each the same amount of the motal energy we call heat, the smaller particles making up for want of weight by greater speed. But, as it requires sixteen times more atoms of hydrogen to make a pound than it does of oxygen, a pound of hydrogen must thus contain sixteen times as much heat as a pound of oxygen. It follows that to raise the temperature of a pound of hydrogen through, say, 10°, requires sixteen times as much heat added as is required in the case of oxygen. Thus, the specific heat increases as the atomic weight diminishes.

The great specific heat of water has a most important relation to the welfare of the living creatures on the globe. The sea, and other great beds of water, which spread over so large a portion of the earth, cannot in the hot seasons of the year become rapidly raised in temperature; in the cold seasons of the year, on the other hand, they cool slowly, and, moreover, in cooling, evolve much heat, which equalises the temperature of the air as well as that of the land.

PROPAGATION OF HEAT.

Heat is transferred from one portion of matter to another in three different ways, which are termed conduction, convection, and radiation. *Conduction* implies the passage of heat from one particle of matter to another in physical contact with it. *Convection* is the conveying or carrying of heat by particles of matter raised in temperature, and set in motion. *Radiation* is the emission of heat by a body such, for example, as a mass of red-hot iron at rest, and not in physical contact with the substances to which it communicates heat. The heat passes in radii, or rays, like those of sunlight, which can find their way even through a vacuum, and do not appear to require the assistance of ponderable matter to determine their transference.

Conduction.

Conduction is best seen in solids, and particularly in metals, which are the best conductors. A rod of iron placed with one extremity in the fire speedily becomes hot at the opposite extremity, owing to the conduction of heat from particle to particle along the rod. Dense bodies are generally the best conductors; light and porous ones the worst; but this rule does not always hold. Feathers, down, fur, flannel, and most of the fabrics used for winter dresses, owe their so-called warmth to their low-conducting power for heat. Their action is altogether negative, being limited to the prevention of the rapid escape of heat generated by the living beings whose bodies they cover. Hence the best way to preserve ice is to wrap it in flannel, or other so-called warm covering; for the same means that retard the escape of heat from the living body, retard the access of heat from the air and surrounding objects to the ice.

The relative conductivities of the principal metals are exhibited in the following table:

Silver	100	Iron	12
Copper	74	Lead	9
Gold	53	Platinum	8
Brass	24	German Silver	6
Tin	15	Bismuth	2

On the same scale, the conductivity of marble would be expressed by ·8, of porcelain by ·6, of brick earth by ·55. Wood conducts fully twice as well in the direction of the fibre as transversely.

Vessels of porcelain and glass are liable to crack when hot water is suddenly poured into them, because these substances conduct heat slowly, and thus the part first touched by the water becomes expanded, while the parts adjoining are yet cold and unexpanded.

Liquids and gases are very bad conductors of heat, although, from the rapidity with which they rise in temperature, when heat is applied to them, they appear to be among the best conductors.

Convection.

Liquids and gases rise in temperature chiefly in consequence of the convection, not the conduction of heat by their particles. If a spirit-lamp is applied to the top of a tube filled with water, the upper portion of the liquid is soon heated to boiling, while hours will elapse before even a slight degree of heat will reach any distance down the column. But if the lamp is applied at the bottom of the tube, the heat is soon felt at the top, and the whole liquid is made to boil in a few minutes. This remarkable difference is owing to a motion that takes place among the particles of the liquid. The portions resting on the bottom, being expanded and made lighter by the heat, begin to ascend, and thus circulating currents are established which *convey* the heat to all parts of the mass. This circulation may be made visible in a glass flask (fig. 20) nearly filled with water, having a few bits of blue litmus swimming in it, and with a spirit-lamp below.

Fig. 20.

Air and other gases are raised in temperature in the same way that liquids are. They conduct heat with extreme slowness, as may be proved by applying heat to the top of an air-tight glass vessel with a thermometer suspended a little below the heated portion. But when the heat is applied from below, currents of circulation immediately begin, as in the case of a liquid.

Our sensations lead us into many errors regarding the temperature of bodies, which attention to their different conducting and conveying powers enables us to correct. Thus, of the several articles in the same room, the table feels colder than the cloth that covers it, and a marble slab colder than the table. They are, in fact, all of the same temperature—the temperature, namely, of the air in the room; but the marble being the best conductor, robs the hand most quickly of its heat.

The cooling effect of a liquid or fluid is much increased by motion, as when the hand is moved through cold water, thus bringing fresh unwarmed portions in contact with it in rapid succession. It is on this last principle that a degree of cold may be borne with a calm atmosphere, which becomes quite killing with even a moderate wind. When air is confined and prevented from circulating, it forms a non-conductor and a warm protection. Hence the effect of double-windows, and of plaster put on laths, so as to inclose a plate of air between it and the wall, instead of being laid on the wall itself. Woolly coverings and furs imprison the air within their substance, and prevent it from circulating, while they afford but few points of solid contact for the direct conduction of heat. These two circumstances combined, give them their remarkable power in arresting the escape of heat; and that power is greater the finer and lighter their texture. Swan's-down is said to be the most perfect insulator of heat. From the same causes, snow is an excellent non-conductor, and, like a fleece of wool, protects the earth from any cold much below 32°.

Radiation.

Every hot body in the act of cooling, besides losing heat by the conductive and convective action of the solids and fluids in its neighbourhood, parts with much heat by radiation. Rays of heat pass away from the hot body till it has reached the temperature of the air or surrounding medium. In proof of this, it is only necessary to hang a hot body in the vacuum of the air-pump, when it rapidly cools, although it does not lose heat by either conduction or convection.

The rate of cooling of a hot solid body, so far as radiation is concerned, is remarkably influenced by the state of its surface, and, in the case of liquids and gases, by the state of the surface of the vessels containing them. Thus, hot water placed in a tin vessel coated externally with lampblack, cools twice as fast as it does in a bright tin vessel. From these observations, it appears that a kettle covered with soot is much less suited for retaining water warm, than if it had a polished metallic surface. So, also, metallic tea-pots and coffee-pots are preferable to those of porcelain and stoneware.

Absorption and reflection of Rays of Heat.—Rays of heat follow almost the same laws as to reflection, absorption, refraction, &c. as rays of light. In fact, radiant heat is manifestly identical with light, differing from red light, for instance, as red light differs from blue—that is, by having longer waves (see SOUND AND LIGHT). When heat-rays fall on the surface of a body, they either enter it or are *reflected*. Those, again, that enter are either *transmitted*, like light through glass, or are retained and *absorbed*. It is only the rays that are absorbed that warm the body; those that are reflected off, as well as those that are transmitted, produce no effect on the temperature.

Surfaces that radiate heat best, are found also to imbibe it most readily. If a table, then, is formed of substances according to their power of radiating heat, the same table will serve for their power of absorption. The following is such a table, the radiating and absorbing power of a surface of lampblack being expressed by 100:

Lampblack	100	Tin	14
White-lead	100	Brass, polished	7
Writing-paper	98	Copper	7
Glass	90	Gold	3
Polished Iron	23	Silver	3
Mercury	23		

Since all the rays not absorbed by a surface must be reflected, this table, read from the bottom upwards, will give the same surfaces in the order of their reflecting powers. It thus appears that the best protection for the head from the burning rays of the sun is a polished metal helmet.

Colour has comparatively little influence on the radiation or absorption of heat so far as *obscure* or non-luminous rays are concerned. In the above table, lampblack and white-lead rank equal; and two garments of the same material, the one white and the other black, dissipate the heat of the body at the same rate, and afford the same protection from the rays of a hot stove. But in regard to *luminous* heat, the case is different. A beam of the sun contains both invisible and visible rays—the former, however, being much greater in amount than the latter. Now, when such a beam falls on two pieces of cloth, one black and the other white, the effect of the obscure rays is the same on both; but the black surface absorbs also the luminous rays, while the white rejects them. The black is thus more heated than the white. As a protection against the direct rays of the sun, light-coloured clothing is thus better than dark.

All bodies, even the coldest, are constantly radiating off more or less heat, according to their temperature; all are therefore both giving and receiving rays; but the warmer give more than they receive, the colder receive more than they give. A surface presented towards the open sky, with nothing to radiate or throw back the rays it is emitting, soon becomes cold; but the slightest curtain, such as a net, hung up before it, sensibly arrests the dissipation of heat. It is in this way that clouds act as warm curtains to the earth, and often prevent frosts in spring and autumn nights. The different radiating powers of bodies explains why dew is sooner deposited on some substances than on others. Those that are good radiators lose their heat most quickly, and thus condense the vapour of the atmosphere.

Transmission of Thermal Rays.—Some substances, it has been observed, allow heat to pass through them, as light passes through glass; such substances are called *diathermanous*. Bodies are not diathermanous and transparent in the same degree; for black glass transmits heat well, and water, which is highly transparent, is the least diathermanous of liquids. Of solid bodies, rock-salt is the most diathermanous, alum the least so. The powers of gases and vapours to transmit radiant heat have recently been investigated by Professor Tyndall, with very striking results. The most important are those concerning the component elements of our atmosphere. Oxygen, nitrogen, and hydrogen transmit almost perfectly, and so does pure air, which is a mixture of oxygen and nitrogen. All the other gases absorb more or less of the rays. If the absorption of air is stated as 1, that of carbonic acid is 90, and of ammonia is 1195. But this is nothing to the absorbing power of the vapour of water. When the atmosphere is in an average state of humidity, the invisible aqueous vapour contained in it absorbs 72 times as much radiant heat as the air itself, although the quantity of the latter is 200 times that of the former. The consequences of this are of vital importance to the inhabitants of our globe. If the atmosphere were without vapour, the sun's rays, both luminous and obscure, would pass through it without warming it, and without losing any of their power, and would scorch the earth's surface while exposed to them; while in the absence of the sun, the radiation from the earth would escape without obstruction, and rapidly produce excessive cold. This effect is partially experienced in elevated positions, where the vapour is comparatively rare; on lofty mountains, the direct rays of the sun are intensely hot, while the air is cold. The vapour of the air thus acts as a blanket to the earth, tempering the direct rays of the sun, and again intercepting the earth's radiation.

Glass transmits luminous rays, but is athermanous to obscure rays; hence, a glass frame, in gardening, has been called 'a trap to catch sunbeams.' The light of the sun passes through the glass, and is absorbed by the earth as heat; but

when this heat seeks to escape by radiation, the glass refuses to retransmit it.

LATENT HEAT.

When a solid body, such as ice, is watched whilst melting, a large quantity of heat is observed to enter it without raising its temperature in the slightest degree. This heat which enters the body serves only to melt or liquefy it, without rendering the liquid the least hotter than the solid was which yielded it. The water which flows from the melting ice is no warmer than the ice. The heat which thus renders a body liquid without warming it, is called *latent* or *insensible* heat, because it does not affect our sensations, and does not raise the thermometer. The fact of heat becoming latent, is most decisively demonstrated by mixing a certain quantity—say an ounce by weight—of ice, or, still better, from its state of division, of snow at 32°, with an ounce of water at 172°. The result will be found to be, that the snow is all melted, and two ounces of water are procured at the temperature of 32°. The hot water in cooling from 172° to 32°, has lost 140° of heat, which changes the snow into water, but does not raise its temperature above that originally possessed by the snow.

What we have illustrated here with ice, holds good for all solids. Each one of them renders latent a certain quantity of heat in becoming liquid, and retains that heat so long as it remains liquid; when the liquid solidifies, it is again given up. Thus, when water freezes, the 140° of latent heat all abandon it, and manifest themselves as sensible heat. It is this necessity of absorbing such a quantity of heat, and getting rid of it again, that makes the processes of thawing and freezing go on so slowly.

In evaporating a liquid, a similar disappearance of heat takes place. In boiling off a pound of water, or converting it into vapour, it can be shewn by experiment that as much heat is absorbed as would have raised its temperature about 1000°, if it had not gone off in steam. Yet the water rises no higher than 212°, however hot the fire is, and the steam is of the very same temperature as the water it rises from. Thus 1000° have disappeared or become latent in the steam; and before the steam can be condensed into water again, all this heat must be given out. See STEAM-ENGINE.

The same is true of the vapour that rises slowly and silently from water at temperatures below boiling (see METEOROLOGY). This absorption of latent heat is the cause of the cold which always accompanies evaporation. By placing water in a shallow vessel under the receiver of an air-pump, and withdrawing the vapour as fast as it rises, evaporation may be made to go on so rapidly that the water freezes.

Heat which thus becomes latent, is not lost; it has done work in producing a change of state in the substance—in loosening the atoms from the rigid bond of cohesion, and remains a fund of potential energy, like a bent bow, ready to become heat again, or be converted into mechanical power, as in the steam-engine. This is another instance of the conservation of energy.

SOURCES OF HEAT.

Next to the sun (see ASTRONOMY), chemical combinations are the chief sources of heat. When two substances unite chemically, their temperature is almost always raised. When the heat is evolved so rapidly as to render the substances luminous—which most substances become when heated to a certain degree—the process is called *combustion* (see CHEMISTRY). *Fire* is a solid rendered luminous or incandescent by combustion; *flame* is gas at a white heat.

Animal heat has the same source as the heat of a fire or of a candle; it arises from a species of combustion. The oxygen taken into the body by the lungs unites with the carbon and hydrogen of the waste parts of the blood and solids, and converts them into carbonic acid and vapour of water—burns them, in short, and thus produces heat. (See PHYSIOLOGY.)

Heat can also be produced by mechanical means, such as compression, percussion, and friction. A piece of iron may be rendered hot by hammering; and axles of carriages often ignite from friction. It is found that the amount of heat thus produced is always in proportion to the mechanical energy expended in the process.

MECHANICAL EQUIVALENT OF HEAT.

The exact relation of the heat to the work that produces it is expressed in what is called *the mechanical equivalent of heat*. A unit of work is the amount expended in raising a pound-weight to the height of a foot, and 10 pounds raised 1 foot, or 1 pound raised 10 feet, makes 10 units of work, or 10 foot-pounds. Now, it has been determined by accurate experiments that 772 foot-pounds of work produce heat sufficient to raise a pound of water one degree in temperature; and 772 foot-pounds constitute the mechanical equivalent of heat. Another way of stating the same thing is to say, that a pound-weight falling from a height of 772 feet against the earth, generates heat sufficient to raise a pound of water one degree; or conversely, that the heat that raises a pound of water one degree in temperature, would, if it could be all used mechanically, raise 772 pounds a foot high. In this way it has been calculated that if our earth were 'to strike against a target strong enough to stop its motion . . . the amount of heat thus developed would be equal to that derived from the combustion of fourteen globes of coal each equal to the earth in magnitude. And if, after the stoppage of its motion, the earth should fall into the sun, as it assuredly would, the amount of heat generated by the blow would be equal to that developed by the combustion of 5600 worlds of solid carbon.'

MECHANICS—MACHINERY.

THE application of the laws of motion and forces to objects in nature, or contrivances in the arts, constitutes the branch of Natural Philosophy usually treated under the head MECHANICS, MECHANICAL POWERS, or ELEMENTS OF MACHINERY.

GENERAL DEFINITIONS.

It is seldom that a force is made to act directly on the body that is to be moved, or the resistance that is to be overcome. In raising coals from a coal-pit by steam-power, the expanding steam is not put below the load of coals, and made to blow it up the shaft, as it were. The steam first raises a piston, which then moves a beam, which in its turn moves a rod connected with a crank; and thus the motion is propagated from one piece of matter to another until it arrives at last at the load. During this transmission the force undergoes various changes which make it act more advantageously for the end in view.

Instruments thus interposed between the moving power and the resistance, with the view of changing the direction of the force or otherwise modifying it, are called *machines* (Gr. *mechanē*, contrivance); and to explain the laws of their action and their various applications forms the subject of the present treatise. Mechanics, in the narrower sense of the term as here used, is understood to treat of the abstract theory of machines, or those general principles, mathematical and physical, on which their action depends; the special application of these principles is the subject of Practical Mechanics, Mechanism, or Machinery.

Machines are of various degrees of complexity; but the simple parts or elements of which they are all composed are few. These are strictly only three in number—namely, 1. The *Lever;* 2. The *Pulley;* and 3. The *Inclined Plane.* These may be called the Primary Mechanical Powers; and from two of them, the Lever and Inclined Plane, other three are formed, as follows: 1. The *Wheel* and *Axle*, from the *Lever;* 2. The *Wedge*, from the *Inclined Plane;* 3. The *Screw*, from the *Inclined Plane.* These may be called the Secondary Mechanical Powers. The six altogether form the most usually occurring elements of complex machinery.

THE LEVER.

When a box, or other heavy body, is lifted in the hands, the power is applied to the weight directly; it acts without the intervention of machinery. But when a bar is used, as represented in the figure, resting on a support F, we have an instance of a machine interposed between the power and the weight. The effect of this machine is to modify the power in more ways than one. When the hand lifts the weight directly, it pulls upwards at the same point and with exactly the same force with which the weight pulls downwards. But with the machine the hand pushes or pulls downwards as well as the weight, and one effect of the solidity of the rod and of the fixed prop is to convert the downward force at P into

Fig. 1.

an upward force at the other end. And not only this, but when the prop is nearer to the weight than to the power, the power seems to be increased; a downward pressure of one pound at P, causes an upward pull of, it may be, two or more pounds at W.

A rod or bar used in this way is called a *lever*, from the French word for 'to raise.' The point of support is called the *fulcrum*, and the distances from the fulcrum to the points of the lever where the *power* and the *weight* act, are called the *arms* of the lever. The lever is the most important of the simple machines, or mechanical powers, and, in its various modifications, enters most extensively into the composition of complex machinery. The law by which it acts, therefore, deserves attentive consideration. To comprehend thoroughly the nature of the *advantage* conferred by the lever, is to comprehend the fundamental principle of all mechanics.

In treating of the *theory* of the mechanical powers, certain assumptions are made. Thus the object of the lever is to *move* the weight; but the question really examined in the theory of the lever, is not what power is necessary to move a certain weight, but what power is necessary to balance it; what force at P will just keep W at rest, or suspended, if unsupported below. The subject is thus considered as belonging to Statics, or the doctrine of forces in equilibrium. It is obvious that when P and W once balance one another, the least additional force to P will suffice to begin motion. Again, it is assumed that machines are themselves without weight; that the rod or lever, for instance, is a mere rigid line. This is done for simplicity; in practice, the weight of the bar itself has an effect on the resistance, and must be allowed for. Another assumption is, that machines move without friction. A certain amount of force is always necessary to turn the lever about its axis or point of support; but this we do not take into the account. The amount of power consumed in overcoming friction, and the means of diminishing it, are questions for practical mechanics.

Law of the Lever.—When the fulcrum of a lever is placed as in the annexed figure, so that one of the arms, FA, is double the other, FB, it is found by experience that a weight of one pound at P

will balance a weight of two pounds at W. And if the arms are in any other proportion—if, for example, AF were made seven feet long, while FB were only two feet; then two pounds at P would balance seven pounds at W. In general, *the power and the weight are to one another inversely as their distances from the fulcrum.* From this it follows, by the well-known property of proportion, that the weight multiplied by its distance from the fulcrum, is equal to the power multiplied by its distance.

Fig. 2.

It looks at first sight like magic that a weight of one pound should be made equal in effect to one of two pounds. It seems as if the lever gave us the means of multiplying force to any amount; as if the strength of a boy might be put on a footing with that of a man. It is necessary to get over this false impression. There is no creation or multiplication of force in the lever, or in any other machine, as will appear from the following considerations. If we suppose the power slightly increased beyond what is necessary to balance the weight, it will begin to descend; but in descending six inches, for example, it will raise W only three inches, as represented in fig. 1. What is thus gained in one way, is lost in another; if we make a small force raise a great weight, the force must be exerted through a proportionally great space. One pound will lift ten pounds; but to lift the ten pounds through one foot it must descend ten feet. The two weights, when thus in motion, have equal momenta; the power multiplied into its velocity, is equal to the weight multiplied into its velocity. Since the velocities are in proportion to the distances from the centre of motion, this is the same as to say, the power multiplied into the length of its arm, is equal to the weight multiplied by its arm.

The comparative spaces through which P and W would move in the first instant of time if their equilibrium were disturbed, are called their *virtual* velocities; and the principle that when P and W balance each other, P multiplied by its virtual velocity is equal to W multiplied by its virtual velocity, is called the Golden Rule of Mechanics, and is true not only of the lever, but of all the other simple machines. This is otherwise, and perhaps better, expressed by saying, that the *rate of doing work* during the movement is the same in the case of the two forces.

The law stated above—namely, that the weight multiplied by its distance from the fulcrum is equal to the power multiplied by its distance, furnishes an easy rule for finding what force is necessary to move a given weight, with a given length of lever; or what weight a given force will move.

Example 1.—Suppose a log of wood, weighing a ton, or 2240 pounds, has to be raised by a lever whose arms are 20 feet and 3 feet respectively, what force must act on the longer arm? Here the product on the one side is $2240 \times 3 = 6720$; what number multiplied by 20 will produce the same product? This is found by dividing 6720 by 20. The quotient 336 is the number of pounds at the long arm, that will balance 2240 pounds at the short one.

Example 2.—Two boys, the one 80 pounds and the other 60 pounds weight, are playing at see-saw with a beam 28 feet long; what point of the beam must rest on the support? The beam must evidently be divided by the fulcrum in proportion to the weights, that is as 80 to 60, or as 8 to 6; which is done thus: $8 + 6 : 8 : : 28 : \frac{28 \times 8}{14} = 16$ feet, the long arm. The short arm is therefore $28 - 16 = 12$. The products on both sides will be found equal; $16 \times 60 = 960$, and $12 \times 80 = 960$.

The power does not necessarily act at the long arm of the lever. The larger weight W (fig. 2) may be used to raise the less P, as well as P to raise W. When the power acts at the short arm, it requires, of course, to be greater in amount than the resistance it has to overcome; but a small motion of the power in this case makes the weight move over a great space; what is lost in power is gained in velocity. This is often as great an object as an increase of power.

As yet we have represented the prop or fulcrum as situated between the power and the weight.

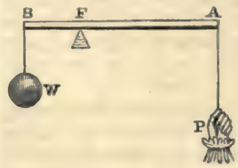


Fig. 3.

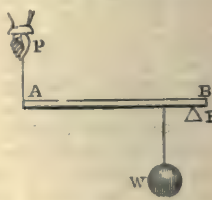


Fig. 4.

This constitutes a *lever of the first kind*, as in fig. 3. But the power and weight may be both on the same side of the fulcrum. In this case, when the weight is between the power and fulcrum, as in fig. 4, the lever is *of the second kind;* and when the power is between the weight and fulcrum, as in fig. 5, it is a lever *of the third kind.*

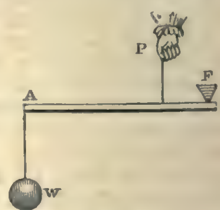


Fig. 5.

These different arrangements make no alteration in the principles already laid down. The effect of each of the forces, P and W, is still measured by its distance from the fulcrum. This distance forms its *leverage* or advantage; and the greater the leverage of either force, so much less does it require to be to balance the other.

The following are examples of implements which act, more or less, on the principle of the lever, beginning with the lever of the first kind.

When the common spade is used in delving, the blade is first forced into the soil by the foot, the handle is then pressed back, the edge of the undelved ground becomes a fulcrum, and the lever-power of the long handle enables a moderate pressure to dislodge the earth from its place. Fig. 6 represents an equally familiar example—namely, a wood-sawyer or carpenter moving a log of timber from its place, by means of a long pole or beam of wood. Stone-masons use a lever of

iron of this description, called a crow-bar. Pincers, scissors, and similar instruments are levers of the

Fig. 6.

first kind with two arms, the rivet at the centre being the fulcrum of both.

A common scale-beam for weighing is an example of the first kind of lever, formed with two arms of equal length.

There is another kind of balance, called a *steel-yard*, which consists of a lever with arms of unequal length, and acts upon the principle of distance from the fulcrum on the long arm compensating for weight on the short arm, as already defined. Fig. 7 is a representation of the steel-yard balance, in which the weight, W, is suspended from the short arm, CA. On the long arm a number of divisions are set off, marked 1, 2, 3, &c.; C1 being equal to CA, C2 equal to

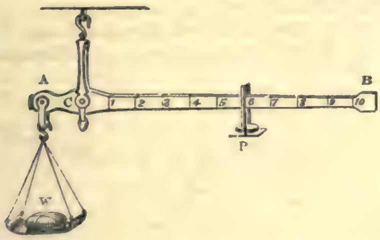


Fig. 7.

twice CA, &c. P is a weight of a certain heaviness, and being movable by a ring, it can be slipped along the bar to any required point. In proportion as the article to be weighed in the scale W is heavy, so is the weight P slipped along to a greater distance from the fulcrum, C; and when it is brought to a point where it balances the article, the figure on the bar at that point indicates the amount of the weight. If P be one pound, and if, when suspended from the division at 6, it balance the weight at W, it is evident that the weight will be six times P, or six pounds. And so on with all the other divisions.

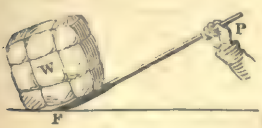


Fig. 8.

The steelyard, though not so ancient as the common balance, is of considerable antiquity. It was used by the Romans, and has long been in use among the Chinese.

Examples of the second kind of lever-power are also common. One of the most familiar is that of a man pushing or lifting forward a bale of goods, as represented in fig. 8, in which the bale or weight W presses against the lever between the power P and the fulcrum F.

Two men carrying a load between them on a pole is also an example of the second kind of lever. In the case of porters carrying a barrel slung from a pole, each man acts as the power in lifting the weight, and at the same time each man becomes a fulcrum in respect to the other. If the weight hang fairly from the centre of the pole, each man will bear just a half of the burden; but if the weight be slipped along, so as to be nearer one end of the lever than the other, then the man who bears the shorter end of the pole supports a greater load than the man who is at the long end. In yoking horses to the extremities of cross-bars in ploughs, coaches, or other vehicles, if the cross-bar is not attached to the load by its middle point, one horse will have to pull more than the other.

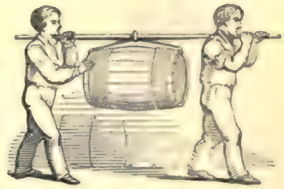


Fig. 9.

The instrument used for cracking nuts (fig. 10) is an example of the second kind of lever with two arms or limbs. The oar of a boat in rowing is also a lever of this kind. The hands of the sailor who pulls, constitute the power; the boat is the weight to be moved; and the water against which the blade of the oar pushes, the fulcrum.

Fig. 10.

In a lever of the third kind, the power must, from its position, be always greater than the weight; and from this circumstance it has sometimes been called the *losing* lever. But this gives a wrong impression; for what is lost in the amount of the power is gained in the velocity, or in the space over which the resisting force is made to move. Levers of this kind are used where the object is not to gain power and overcome great resistance, but to produce rapid motion where the resistance is comparatively small.

An example is found in the footboard of the turning-lathe (fig. 11). The foot of the workman presses on the board or plank near the end which rests on the ground, or fulcrum, and, at the cost of a short movement of its own, causes the opposite extremity of the board to move in a downward direction over a considerable space.

Fig. 11.

The movements in the limbs of animals are mostly produced by the action of levers of the third kind. The tendons or ropes which move the bones are attached near the joints, which are the pivots or fulcra of the bone-levers. The structure of the human arm (fig. 12) is a very good example. The fulcrum is the socket, C, of the

elbow-joint; the power is the strong muscle called the *biceps*, which passes down the front of the *humerus*, and is attached at A to the *radius*, one of the two parallel bones composing the forearm;

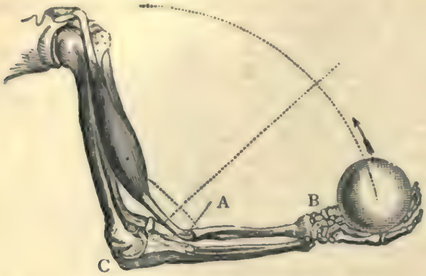


Fig. 12.

the resistance is the weight of the forearm, together with anything held in the hand, the two being supposed combined in one weight acting at B. In this way, the contraction of the muscle to the extent of an inch will raise the hand through an arc of twenty inches. It will be readily seen, that as the angle at the elbow-joint is enlarged, the tendon of the muscle pulls more obliquely to the bone of the forearm, and thus acts at an increasing disadvantage; hence the arm held out straight has comparatively little power to sustain a weight.

Combinations of Levers.

By disposing a number of simple levers, so that the one shall act on the other, the effect of the power may be increased to any desired degree. Fig. 13 represents a combination of three levers of

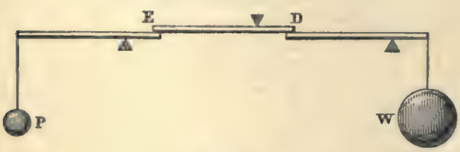


Fig. 13.

the first kind. They are supposed, for simplicity, to be of equal length, the long arms being six inches each, and the short ones two inches each; required—the weight which a moving power of 1 pound at P will balance at W. In the first place, 1 pound at P would balance 3 pounds at E, according to the rule of calculation for the simple lever; for $1 \times 6 = 3 \times 2$. This upward pressure of 3 pounds at E is next converted, by the second lever, into a downward pressure at D three times as great, or equal to 9 pounds; and, lastly, the downward pressure of 9 pounds at D is converted, by the third lever, into an upward pull at W of 3 times 9, or 27 pounds. Thus, 1 pound at P will balance 27 pounds at W.

The general rule for combinations of levers, whether equal or not, is, that the power multiplied successively by all the arms next it in the system, is equal to the weight multiplied by all the other arms. From this equation we may find what power will be necessary to raise any given weight, or what weight any given power will raise.

Machines for weighing loaded wagons, frequently seen at toll-bars, consist of a system of levers arranged below a table or platform on the level of the road. The wagon being wheeled upon the platform, is balanced by a comparatively small weight attached to the extremity of the system. The balance of Quintenz, much used for weighing luggage at railway-stations, is an ingeniously arranged combination of levers. The principle of the steelyard is frequently superadded to a combination of levers in these weighing-machines, so that one counterpoise serves for all cases.

So long as a force acts perpendicularly to the straight arm of a lever, its effort to turn the lever about the centre is the same, whatever angle that arm makes with the other arm. If the equal forces, P, Q, act perpendicularly to the equal arms CA, CB, of the bent lever ACB (fig. 14), they will keep each other in equilibrium on the same grounds as when the lever is supposed straight; namely, that there is no cause why the one should prevail over the other. And if we suppose the arm CA removed and again fixed in the position CA′, with an equal force P′ acting in the perpendicular line A′P′, the force Q will still be balanced as before; that is, the effort of the force P to turn the lever is the same in its new position as it was in its old.

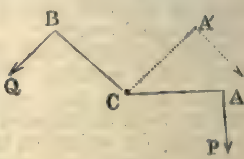


Fig. 14.

Suppose, now, that two unequal forces, P and Q (fig. 15, *a*), hold one another in equilibrium on the

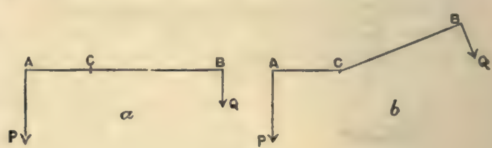


Fig. 15.

unequal arms AC and CB, and let the arm CB take the position shewn in *b*, the effort of Q to turn the lever will not be altered by its new position any more than in the case of the equal arms; so that Q and P still balance each other. It is thus of no consequence what angle the two arms of a lever make with each other, so long as the forces act at right angles to the arms; $P \times AC$ is still equal to $Q \times BC$.

But when a force acts obliquely to its arm, part

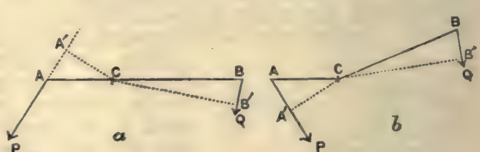


Fig. 16.

of it is wasted in pulling or pushing against the fixed centre, and the virtual or effectual leverage

is found by drawing a perpendicular from the fulcrum or centre to the direction of the force. In fig. 16, *a* and *b*, CA′ and CB′ are the virtual arms, and P . CA′ = Q . CB′.

When a force thus exerts an effort to turn a lever or any system about a centre, the value of the effort is found by multiplying the force by the perpendicular drawn from the centre upon the direction of the force. This product is called the *moment* of the force.

THE WHEEL AND AXLE.

Let the larger circle in the fig. represent the rim of a wheel, and the smaller the section of the cylindrical axle on which it is fixed. A small weight, P, attached to a cord wound round the wheel, is sufficient, by its descent, to wind up a large weight, W, attached to another cord wound round the axle. It is evident that the two forces here act on the unequal arms, FA, FB, of a lever whose fulcrum is F; therefore P × AF = W × FB. As the system turns round, the points A and B, at which the forces act, are constantly changing, and there is a succession of new levers, as it were, the arms, however, continuing always of the same length; the machine is therefore sometimes called the *perpetual lever*.

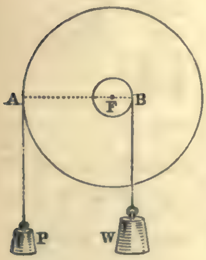


Fig. 17.

We can conceive the wheel removed, and nothing left but the axle and one radius or spoke, FA. If now a projecting handle is inserted into the end of FA, the weight P may be dispensed with, and the force of a hand of equal amount applied at A will turn the axle round and wind up W. Such a spoke and handle attached to an axle is called a *winch*, and is another form of perpetual lever.

The principle of the wheel and axle, or perpetual lever, is introduced into various mechanical contrivances, which are of great use in many of the ordinary occupations of life. One of the simplest machines constructed on this principle is the common windlass for drawing water from wells by a rope and bucket. Coal is lifted from the pits in which it is dug by a similar contrivance, wrought by horse or steam power.

The capstan in general use on board ships for hauling or drawing up anchors, and for other operations, is an example of the wheel and axle, constructed in an upright or vertical, instead of a horizontal, position.

There are combinations of the wheel and axle, as there are combinations of the simple lever. Cranes, watch and clock work, and wheel-machinery in general, mostly consist of such combinations. The parts are usually made to act upon one another by means of projections called *teeth* or *cogs;* or, when at a distance, by straps. In any case, the advantage is calculated in the same way as in combinations of the lever. For illustration, let us take the combination of three wheels and axles represented in fig. 18; and suppose that the radii of the wheels A, B, and C are 12, 15, and 20 inches respectively; those of the pinions F and G, 3 inches each, and that of the axle E 2 inches—the radii of the toothed-wheels and pinions being measured from the centre to the point of contact of the teeth. By the principle of the lever, the downward force of P becomes an upward pressure on the teeth of wheel B, and is increased as 3 to 12, or made fourfold. Similarly, the upward pressure on the teeth of wheel B becomes a downward pressure on those of C, and is increased as 3 to 15, or five times; that is, it is equal to 20 times P. Again, this downward pressure of 20 times P upon the teeth of C becomes an upward force at E, increased as 2 to 20, or 10 times; so that W is sustained by a force equal to 200 times P.

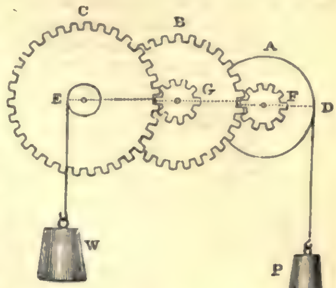


Fig. 18.

The object of wheel-work is often, not to gain power, but to gain velocity at the expense of power. In this case the moving force is applied as at W, and the gain in velocity in the revolution of the last wheel in the system, might be calculated from the radii, in much the same way as the gain in power is calculated. It may also be calculated from the number of teeth in the several wheels and pinions.

THE PULLEY.

The pulley consists of a small wheel, called a sheaf, turning on an axis in a block, with a flexible cord resting in a groove in the circumference of the wheel. There are two kinds of pulleys—the *fixed* and the *movable*.

The annexed cut represents a pulley, A, fixed by its block or frame to a beam or roof, B, and having two weights attached to the ends of the cord. In order that P and W may be in equilibrium in this case, it is evident that they must be equal. This appears from the wheel acting as a lever with equal arms, so that neither P nor W has any advantage. It is also plain that the cord, being free to move either way, must be equally stretched, or have the same *tension* throughout its whole length. A fixed pulley, therefore, does not increase the power; it only serves to change the direction in which the power acts. This is often as great a gain as increase of power would be. A force, for instance, at P, pulling downward, can raise W upward.

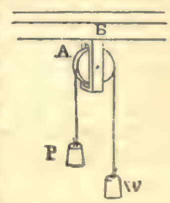


Fig. 19.

The wheel is not an essential part of the pulley, in theory at least. The same object might be gained by bending the cord over the axis of the wheel, or over any bar, and making it slide on it; but in this case the friction of the cord on the surface of the bar would cause great resistance, and would chafe the cord; and it is to obviate this that the

wheel is used. Theoretically, then, the whole virtue of the pulley resides in the flexible cord.

It is only with the movable pulley that there is a gain of power. The movable pulley is generally attached to the weight or resistance, and moves along with it. In the annexed cut, a cord is carried from a fixed point at A round a pulley B, from which the weight is suspended; it is then made to pass over a fixed pulley at C, and the power is represented by a hand drawing downwards. The parts of the cord BA and BC being equally stretched, each sustains evidently *half* the weight; but the part of the cord PC has the same tension as the rest, therefore P pulls down with a force equal to half the weight. A single movable pulley, then, *doubles* the effect of the power. The only effect of the fixed pulley C is to change the direction; if the hand were at C pulling upwards, it would sustain just half the weight.

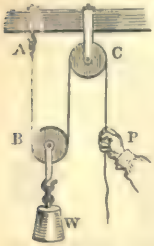


Fig. 20.

When the two cords, BA, BC, are not parallel, besides sustaining the whole weight, they pull against each other to a greater or less degree, and are therefore stretched with a tension greater than that due to half the weight. Part of the advantage, then, is lost when the strings attached to the movable pulley are not parallel.

The secret of the saving of power in the movable pulley lies in making the hook in the beam at A support the half of the weight. It is as if there were two hands, one at A, and another at C, sustaining the weight between them; but, although the hook A can thus act as a substitute for a hand to sustain W at rest, it can take no share in *lifting* W. In order to lift W one foot, the hand at C must rise through two feet, or—which is the same thing—the hand at P must descend through two feet. We thus find the same principle in the pulley that has been illustrated regarding the lever.

Technically, the wheel of a pulley is called a *sheaf;* for protection and convenience, this sheaf is ordinarily fixed with pivots in a mass of wood called a *block;* and the ropes or cords are called a *tackle.* The whole machine, fully mounted for working, is termed a *block and tackle.* By causing a wheel and axle to wind up the cord of a block and tackle, the power of the lever is combined with that of the pulley in the operation.

Systems of Pulleys.

Several pulleys are often used in combination, forming a *system of pulleys.* There are various modes of arrangement. One of the most common is that represented in fig. 21, and called the 'First System,' in which the same cord passes over all the pulleys, and the pulleys are divided into two sets—one set working in the same fixed frame or block, and the other set in a movable block to which the weight is attached. The cord being the same throughout, the tension of all its parts is the same; and, therefore, neglecting any slight want of parallelism among the cords, the weight is equally distributed among the cords 1, 2, 3, and 4. As the cord at P has the same tension as the others, being, in fact, a continuation of the same cord, P thus sustains a fraction of W, depending upon the number of cords that join

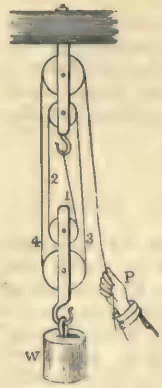


Fig. 21.

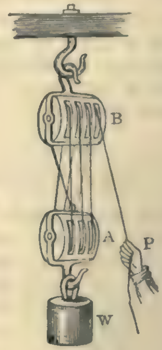


Fig. 22.

the movable block. In the present case, P is one-fourth of W, or $P = \frac{W}{4}$, or $4P = W$; so that a weight of a cwt. at W would be sustained by a weight of 28 lbs. at P.

Fig. 22 represents another mode, commonly used in practical operations, of constructing a system of pulleys on the principle of the same cord passing over all the sheaves. As seven cords join the lower block, $P = \frac{W}{7}$.

THE INCLINED PLANE.

If AB (fig. 23) represent a horizontal plane, AC will represent a sloping or *inclined* plane. If we suppose AC to be a plank resting on the ground at A, and with its other end at C on the edge of a platform, it is a familiar fact, that a man can roll a heavy cask from A to C, which it would be far beyond his strength to lift perpendicularly from B to C. In such a case, the inclined plane is used as a mechanical power.

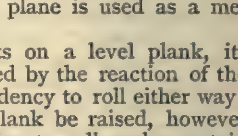


Fig. 23.

When a cylinder rests on a level plank, its whole weight is supported by the reaction of the plank, and it has no tendency to roll either way; but if one end of the plank be raised, however slightly, the cylinder begins to roll, and a certain force is required to keep it at rest. As the end is more and more elevated, the restraining force requires to be increased, and at the same time the pressure on the plane becomes less, until, when the plank comes into the upright position, it ceases to sustain any pressure, and a force equal to the whole weight of the cylinder is required to keep the latter in its position.

In order to find the relation of P to W in a given inclined plane, we have recourse to the resolution of forces. In fig. 24, which represents a cylinder resting on a plane, and kept from rolling down by a weight suspended over a pulley at *p*, so placed that *cp* is parallel to AB; let *cf*, drawn

from the centre of gravity of the cylinder in a vertical direction, represent the whole weight of the cylinder. This force may be resolved into two others, *ce* perpendicular to the plane, and *cg* parallel to it (see No. 13). But *ce* is counteracted by the resistance of the plane, and can produce no effect; therefore *cg* or *ef* represents the force with which the cylinder is urged in the direction of BA; *fe* will therefore represent the force of P which keeps W in equilibrium. Now, it can be shewn that the triangle *cfe* is similar to the triangle ABD; therefore *fc* is to *ef* as AB to BD—that is, *W is to P as the length of the plane to its height.* If AB is twice the length of BD, one hundredweight at P will sustain two hundredweight at W; and if AB is six times the length of BD, W will be six times P.

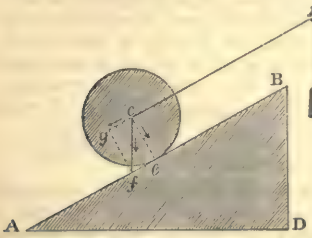


Fig. 24.

The proportion of P to W now stated is true only when the direction of the force P is parallel to the plane; in any other direction, part of the effect of P is lost.

In speaking of sloping roads, they are said to have an inclination or rise of one foot in ten, one in thirty, one in a hundred, and so on. The degree of slope in a railway is called the *gradient*, and seldom exceeds one in 50 or 60. The annexed cut represents a cart drawn by a horse up a common road with a rise of one in ten. On a perfectly level road, a certain force of draught would be required to overcome friction (see page 222); on the incline there is required, in addition to this, a constant pull to counteract the tendency of the cart to run down the slope. That tendency is, in this case, equal to a tenth of the weight of the load; and if the load is a ton, the horse has to pull with a force of one-tenth of a ton, or 224 pounds, above what would have sufficed to draw it along a level.

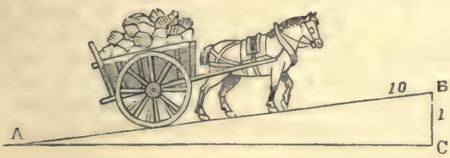


Fig. 25.

In going over ten feet of the road, the horse has raised the cart one foot perpendicularly, but he has done it by instalments; the exertion has been spread over a movement of ten feet. Intensity of exertion is saved at the expense of time.

THE WEDGE.

A common form of the wedge is represented in fig. 26. By forcing such a body below the bottom of an upright post, for instance, which can move only vertically, we may raise the post a few inches. It obviously acts on the principle of the inclined plane; it is, in fact, the inclined plane made movable.

Fig. 26.

The proportion of the power to the resistance in the wedge is calculated theoretically in the same way as in the inclined plane. But the theory is of little or no value. The power employed being percussion or blows, cannot be rightly compared with the resistance; it cannot be estimated in pounds, like other forces. The friction, too, is so great as to render any precise statement of proportion impossible. In a general way, however, the wedge is more powerful as the angle is more acute; just as the advantage of the inclined plane increases with the smallness of its height.

The wedge is used in splitting timber, stones, &c. Ships are raised in docks by driving wedges under them. In expressing oil from seeds, the seeds are placed in bags between solid pieces of wood, and these are forced together by means of wedges, till the seeds become a mass as compact as wood.


Fig. 27.

Cutting and piercing instruments all act on the principle of the wedge. The plough is also an instance.

THE SCREW.

The screw is an inclined plane wound round a cylinder. Take a cylindrical ruler AB, and cut a slip of paper in the form of a right-angled triangle *abf*, having *ab* equal to the length of the cylinder, and *bf* equal, say, to four times its circumference. If the edge *ab* is applied to the cylinder lengthwise, and the triangle is then wrapped round and round, the slanting side, *af*, will form a spiral going four times round the cylinder before it reach the bottom. In the fig. to the left of the cut, it is represented as half wrapt on.

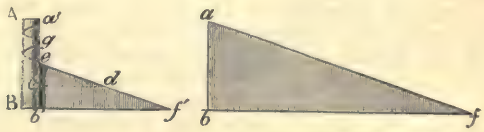


Fig. 28.

If a ridge or projection were raised on the cylinder along the spiral line, it would form a screw. The several turns or coils of the spiral are called the *threads* of the screw; *ed* represents the *length* of one thread, and *ec* the *distance between the threads.* In moving over a complete round of the spiral, a perpendicular ascent or descent is made equal to *ec*. As in the inclined plane, therefore, the mechanical advantage of the screw depends on the proportion between the length of a thread and the distance between two contiguous threads.

In using the screw as a machine, the resistance is not applied directly to the spiral surface, as in the wedge or the straight inclined plane; the screw is made to work in a hollow cylinder with spiral grooves cut out to correspond to the projecting threads. This concave screw is technically

called a *nut*, as represented at M, fig. 29. The threads and corresponding grooves are sometimes of a triangular form, as in fig. 29; and sometimes flat. To produce pressure with the screw, either the screw or the nut must be fixed. Whichever is free, is then turned, and made to press against the resistance.

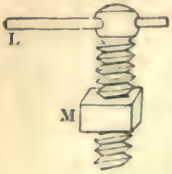


Fig. 29.

Practically, the screw is never used as a simple machine, the power being always applied by means of a lever, passing either through the head of the screw or through the nut. The screw, therefore, acts with the combined power of the lever and inclined plane; and in investigating the effects, we must take into account both these simple mechanical powers, so that the screw now becomes really a compound machine.

To arrive at the proportion of the power to the weight in this compound machine, we may apply the principle of virtual velocities. The power acts at the end of the lever L (fig. 29), and in turning the screw once round, it describes a circle, of which the lever is the radius. The circumference of this circle represents the velocity of the power. In the meantime, the weight has moved over a space equal to the distance between two threads, which is its velocity. Therefore, *in the screw, the power multiplied by the circumference it describes, is equal to the weight multiplied by the distance between two contiguous threads.*

Applications of the Screw.

The most common purpose for which the screw is applied in mechanical operations, is to produce great pressure accompanied with constancy of action, or retention of the pressure; and this quality of constancy is always procurable from the great friction which takes place in the pressure of the threads on the nut, or on any substance, such as wood, through which the screw penetrates.

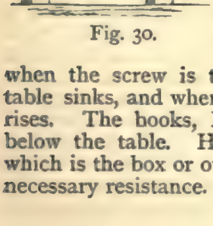


Fig. 30.

The common standing-press used by bookbinders for pressing their books, affords one of the best examples of the application of the screw to produce great pressure (fig. 30). The screw A has a thick round lower extremity B, into holes in which the lever is inserted. This extremity B is attached by a socket-joint to the pressing-table C, so that when the screw is turned in one direction, the table sinks, and when turned in another, the table rises. The books, D, lie upon a fixed sole S, below the table. H is a cross-beam above, in which is the box or overlapping screw, to give the necessary resistance.

STRENGTH OF BODIES AND OF STRUCTURES.

A knowledge of the simple principles of mechanics above considered, together with that of the general properties of matter, enable us to determine what forms of bodies and what positions are best calculated to resist forces that tend to break, crush, or overthrow them. This constitutes engineering. A few of the more important general truths thus arrived at may be here noticed.

The strains to which the parts of machines and edifices are subjected, are chiefly of four kinds: 1. Tension, as when a rope is pulled in the direction of its length; 2. Compression or crushing; 3. Transverse or Cross Strain; and 4. Torsion or twisting.

Tension.

When a rod of wood is suspended vertically, and a weight attached to it tending to tear it asunder, all its fibres act equally, and its strength evidently depends on the strength of the individual fibres and their number—that is, the area of the cross-section of the rod. If there are two rods, then, of the same material, the one having an area of one square inch in its cross-section, the other an area of three square inches, the last will sustain three times the weight that the other will sustain, and this whatever be the shapes of the sections. The same reasoning applies to a rope or a rod of iron or other metal.

The power of bodies to resist tension or tearing force, is called their Tenacity, Direct Strength, Absolute Strength, or Tensive Strength. It depends upon the force with which their atoms cohere; and differs in different substances. The following are the absolute or tensive strengths of some of the more important materials, as determined by experiments: A rod of ash, 1 square inch in section, sustains a weight of 17,000 lbs.; a similar rod of English oak, from 8000 to 12,000; of red pine, 12,000; cast-iron, 18,000; wrought-iron, 29 tons or 65,000 lbs.; iron wire, 41½ tons or 93,000 lbs.; cast-steel, 134,000 lbs.; copper, 21 tons or 47,000 lbs.; hempen rope, 6000 lbs. From these numbers the tensive strength of a rod or beam of any given dimensions may be found, by multiplying by the number of square inches in the section of the rod or beam. *Ex.* What weight will a cylindrical rod of wrought-iron, 3 inches in diameter, sustain? Here area of section is $3^2 \times \cdot 7854 = 7 \cdot 0686$ square inches; and $29 \times 7 \cdot 068 = 205$ tons, nearly.

Compression.

Numerous experiments have been made on the power of different materials to resist crushing force; but no law has been found by which we can deduce with any accuracy the strength of bodies of dimensions different from those experimented upon.

Transverse Strain.

Let *ab* be a beam fixed at one end into a wall *ag*, and loaded with a weight W at the other end. If the beam is to break (supposing it of uniform dimensions throughout), the rupture will evidently be at the wall, because there W acts with the greatest leverage. Before actual rupture, a portion of the fibres in the upper part of the section from *a* to *c* are drawn out or stretched, and a portion in the lower part, from *c* to *f*, compressed; and there must therefore be a line of fibres somewhere, as at *c*, which are neither stretched nor compressed. This line is called the *neutral axis of rupture;* and as W tends to bring the beam into the position marked by the dotted lines, we may conceive *c* to be the fulcrum of a bent lever with three

arms, of which W acts on the long arm *cn′*, *ce* and *cd* being two short arms at right angles to *cn′*. The fibres of the upper part of the section (which we suppose not yet ruptured, but only extended)

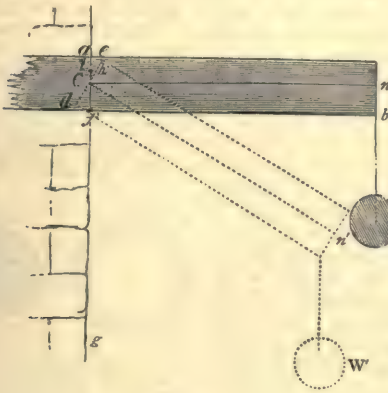


Fig. 31.

are acting all along the arm *ce*, as at *ik*, *ae*, drawing it towards the wall; while those in the lower part are resisting compression, and pushing the arm *cd* away from the wall. Both these sets of forces resist the tendency of W to turn the lever about the axis *c*, and thus together constitute the strength of the beam. The effects or moments of the two sets must evidently be equal to each other; for the neutral axis so adjusts itself that the amount of resistance on the one side balances that on the other. If the tensive strength of the fibres is equal to their compressive strength, the neutral axis will be in the middle of a rectangular beam; if the tensive strength is greater, the neutral axis will be nearer the upper side; and *vice versâ*.

But the most important point to observe in this investigation is that the fibres are not all equally well situated for offering resistance. A fibre at *a*, for instance, acts with twice the leverage of one at *i*, supposing *i* in the middle of *ca*. If we call the tensive strength of a fibre of certain area 1, its moment or efficacy at *a* will be expressed by $ca \times 1$, or simply *ca*; while the moment of a similar fibre at *i* will be $ci \times 1$, or *ci*. The sum of the moments of a row of fibres from *c* to *a* would thus be expressed by the number of such fibres multiplied by their *mean distance* from *c*, which is $\frac{1}{2}\,ca$. Since the number of fibres along the line *ca* increases with the length of the line, we may take that length to represent the number; and therefore, the sum of the moments will be $ca \times \frac{1}{2}\,ca$, or $\frac{1}{2}\,ca^2$. But the resistance to compression made on the arm *cd*, is equal to the resistance on *ca*; therefore, the whole resistance to fracture made by a line of fibres from *a* to *f*, is expressed by (2 times $\frac{1}{2}\,ca^2$ or) ca^2. And if we put *b* for the breadth of the beam, the whole strength of the beam is expressed by $b \times ca^2$.

From a variety of causes, the formula above given does not enable us to calculate at once the transverse strength of a beam from merely knowing the tensive strength of a rod of its fibres. One of these causes is that we have no means of determining where the neutral axis is situated. The formula, however, serves this valuable purpose, that when the actual transverse strength of one beam of certain dimensions has once been determined by experiment, it enables us, from this data, to calculate the strength of another beam of the same general form, but of different dimensions. For, whatever fraction *ac* is of *af*, in a beam of any material, it is the same fraction in all beams of that material, or the length of *ac* varies with the length of *af*; and, therefore, to express the relative strengths of beams, we may put *af* in the formula instead of *ac*. If, then, we put *d* for the depth, or *af*, the formula becomes $b \times d^2$, which expresses the leading proposition in the strength of materials, that THE TRANSVERSE STRENGTH OF A BEAM INCREASES AS THE BREADTH MULTIPLIED BY THE SQUARE OF THE DEPTH.

The truth of this important proposition is fully confirmed by experience, and is constantly acted upon in all kinds of constructions. Rafters, joists, &c. are never made square in the section; but as deep as possible, and no thicker than is necessary to prevent them from bending laterally, or *buckling*, as it is called. Strength is thus gained, and material saved. *Ex.* Let A (fig. 32) be the section of a square wooden beam of 10 inches in the side, and B that of another beam of the same wood, 5 inches broad by 20 deep. The areas of the two sections are equal, being 100 square inches each; but the transverse strength of A is as $10 \times 10^2 = 1000$, and that of B is as $5 \times 20^2 = 2000$. B has thus double the strength with the same amount of material. When the breadth of a beam is doubled, retaining the same depth, the strength is merely doubled; when the depth is doubled, retaining the same breadth, the strength is quadrupled.

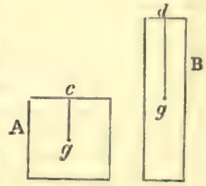


Fig. 32.

In order to make this expression available for finding the actual weight that any beam will bear, small beams or prisms are taken, of the most usual materials, having a section of one square inch, and a length of 12 inches, and loaded with weights till they break. The breaking weights of these small bars are then used as *constants* or coefficients, for calculating the breaking weights of other beams of the same materials. The following are a few of the results of experiments made on small bars fixed and loaded as in fig. 31:

Ash	2030	Oak, English	from..1200 to....2260
Elm	1030		
Fir, Scotch	1140	Cast-iron	8100
Red Pine	1340	Wrought-iron	9000

To find the weight that will just break a beam of given dimensions, we have only to multiply the constant for the material in the table by the breadth and square of the depth, and divide by the length—the dimensions being all reduced to inches; or, employing the formula, $W = \text{Constant} \times b \times d^2 \div l$. *Ex.* What weight will break a beam of Scotch fir, fixed at one end, and loaded at the other, its breadth being 3 inches, depth 11 inches, and length 9 feet? *Ans.* $W = 1140 \times 3 \times 11^2 \div 108 = 3832$ lbs. nearly.

When the beam is cylindrical, find the strength of a square beam, whose side is equal to the diameter of the cylinder, and take two-thirds of the result. *Ex.* What is the strength of a round

beam of ash, diameter 10 inches, and length 12 feet? Here $2030 \times 10 \times 10^2 \div 144 = 14097$ lbs. the strength of a square beam of 10 inches in the side. But a cylindrical beam of 10 inches diameter has less area by about one-third, and therefore its strength will be $14097 \times \frac{2}{3} = 9398$ lbs. More exactly, the square is to the circle as 1 to ·7854; and $14097 \times{} ·7854 = 11071$ lbs.

The most frequent case of transverse strain is that of a beam resting freely on supports at the two ends, with a weight or weights pressing somewhere between. If the weight rests on the middle point, as in fig. 33, each of the supports sustains a pressure equal to $\frac{1}{2}$ W. We may therefore consider the reaction of either of the supports, B, as a force acting upwards, and tending to break the beam at C, while the two forces at A and C merely hold the end of the beam fixed, as the wall does in fig. 34. The moment of the force of rupture is thus $\frac{1}{2}$ W × CB = $\frac{1}{2}$ W × $\frac{1}{2}$ AB = $\frac{1}{4}$ W × AB. But if the beam were fixed in a wall at A, with a force W acting at B, the moment would be W × AB. That is, *a beam supported freely at both ends will support four times as much weight at its middle point, as it would if fixed at one end, with the weight resting on the other.*

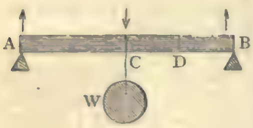


Fig. 33.

Ex. A bar of cast-iron, 2 inches square and 15 feet long, is supported at both ends, what weight applied at its middle will break it? Such a bar, if fixed and loaded as in fig. 31, would support, by the former rule, $8100 \times 2 \times 2^2 \div 180 = 360$ lbs. The breaking-weight in the present case is, therefore, $360 \times 4 = 1440$ lbs.

The strain of W is greater when applied at C, the middle point, than when applied at any other point, D.

Form of Greatest Strength.—It is evident (see fig. 31) that the fibres of a beam near the neutral axis on both sides, have little efficacy in resisting rupture, and might be removed without much affecting its strength; and this principle is largely applied in constructing metal beams or girders, in order to produce the greatest strength with the least material. For girders of cast-iron, resting on both ends, and loaded in the middle, the form of section adopted is that of an inverted T (fig. 34). Cast-iron has much less power of resisting extension than compression, and therefore the lower *flange* is made much greater than the upper, so as to throw the neutral axis as nearly as possible in the middle of the beam; for the sum of the moments of the two sets of resistances is greater when the axis is in the middle than when it is anywhere else. With wrought-iron, which resists extension better than compression, the upper flange is made the larger. The advantage of the T-form is, that the great mass of the material being collected on the two flanges, acts at the greatest possible leverage. In a series of experiments with cast-iron beams, the strongest form was found to be that represented in fig. 34, in which the lower flange, *cd*, is six times the area of the upper, *ab*. With this proportion, the strength per square inch of section of the whole beam was 4075 pounds, whereas 'in the best form of girder used before these experiments, there was never attained a strength of more than 2885 pounds. There was, therefore, by this form a gain of 1190 pounds per square inch of the section, or of $\frac{2}{5}$ the strength of the beam.'

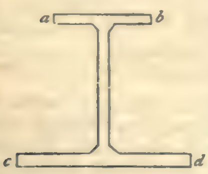


Fig. 34.

Hollow or Tubular Structure.—Another way of throwing the great body of the material at a distance from the neutral axis is, to make it into the shape of a tube or hollow cylinder. Let B be the section of a hollow cylinder, the thickness of whose walls is represented by the shaded ring; and A be the section of a solid cylinder of the same material. If the area of A is equal to that of the ring in B, the two cylinders will contain the same quantity of matter, but B will be stronger than A, in proportion as *cg* is longer than *dg*.

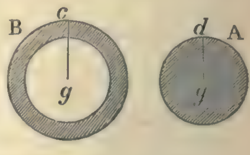


Fig. 35.

The principle of hollow structure prevails both in nature and art, wherever strength and lightness have to be combined. It is seen in the stems of plants, especially of the grasses; the bones of animals are also hollow, and those of birds, where great lightness is required, are most so. A feather, with its hollow stem, is perhaps the best instance of the union of strength and lightness that could be given. In art, again, we have hollow metal pillars; and sheet-iron for roofing and other purposes is *corrugated*, or bent into ridges and furrows, to give it depth. Each ridge or furrow is, as it were, half a tube, and resists bending with twice or thrice the energy it would if flat.

The most striking application of the principle of hollow structure is seen in Tubular Bridges. Fig. 36 represents a section of the tube of the Conway Bridge. The object being to resist a vertical strain, the form is made rectangular, and the chief mass of the material is thrown into the top and bottom. The tube may, in fact, be considered as an immense beam or girder constructed on the principle of fig. 34, the top and bottom being the two flanges, and the two sides serving to connect them, instead of the one rib in the middle. As it is constructed of plate-iron, the top requires more metal than the bottom, in order to resist the compression; but instead of putting the metal into one thick plate, or into several plates laid the one on the other, it is made to form a set of minor tubes or cells, which gives additional stiffness and strength to the whole tube. The floor, in like manner, contains cells. Each of the tubes over the Conway is 24 feet high, 14 feet wide (outside), and 420 feet long, and weighs 1300 tons; yet these enormous hollow beams sustain not only their own weight,

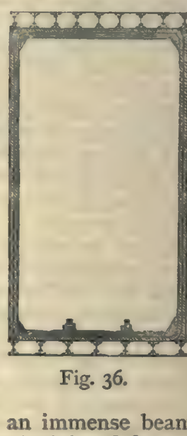


Fig. 36.

but the heaviest railway-trains without sensible deflection.

In beams supported at both ends, the strain is greatest in the middle; girders are therefore made strongest in the middle, and taper towards the ends.

Torsion.

If one end of the axle or shaft of a wheel is immovably fixed, and a power acts at the circumference of the wheel (or at the end of a lever or winch), the power may be so increased as to twist the shaft asunder at its weakest point. If a shaft A has twice the diameter of another shaft B, there will be four times as many fibres in the section of fracture of A, to resist the twist, as in that of B. But as the separation takes place by the one end of the fracture turning round upon the axis of the shaft, making the ends of the separating fibres describe circles, those fibres that are furthest from the centre will have the greatest power of resistance, and the sum of their moments, or their united effect, will be in proportion to their mean distance from the centre. This mean distance in A is twice that in B; therefore, the resistance in A is 2×4 or 8 times the resistance in B. Generally, ***the strength of shafts to resist torsion is as the cubes of their diameters.*** On the other hand, the twisting force that may be applied to the wheel or lever will be less as that lever is longer. The torsive strengths of shafts 1 inch diameter, and with weights acting at 1 foot leverage, being found by experiment for different materials; the strength of shafts of other dimensions are found from these 'constants' by multiplying by the cube of the diameter, and dividing by the length of the lever. It is evident that the torsive strength of a hollow shaft will be greater than that of a solid one of the same quantity of material, on the same principle that its transverse strength is greater.

MACHINERY.

The object of all machinery is to transmit and modify motive-power. It is not, as already explained, to create or multiply power; for no machine can give off more working-power at one part than has been applied to it at another. The most usual and convenient form of motive-power is rotary or circular motion; having once a motion of this kind, we can transmit it to any point where it is required, and can alter its velocity, and change it into another kind of motion, at pleasure. The more important elements of machinery by which these purposes are effected, we now proceed to notice.

COMPONENT PARTS OF MACHINERY.

Shafts.—A rigid bar of metal or wood made to revolve on its axis by any motive-power applied at one part, is capable of conveying and giving off that power at any part of its length to machinery connected with it. A large bar or beam of this kind is called a *shaft;* a smaller one, a *spindle.*

The part of a shaft on which it rests while turning is called the *journal* or *gudgeon.* The *bearings* of a shaft are the rests in which its journals or ends turn. The lower bearing of a vertical shaft is called a *step.*

Bands or Straps.—Bands or straps are used to convey motion from one shaft to another parallel and distant shaft. In fig. 37, A is a *drum* or *pulley* with a flat surface, supposed to be fixed on a shaft put in motion by the source of power; B is another pulley fixed on the shaft S; and over the surfaces of the two a broad leather belt, L, is stretched tight. As A turns, the friction between its surface and that of the belt carries the latter along with it, and thus B is also made to revolve. The shaft S thus set in motion may be made to communicate rotation to any number of pulleys and spindles, C, E, each of which may drive a separate apparatus. The main stream of driving-power is thus distributed into a number of small rills.

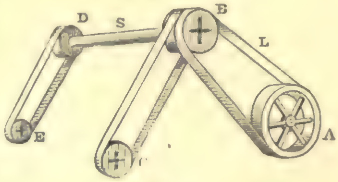


Fig. 37.

In order to economise the power, the band should have no more tightness than is just sufficient to prevent its slipping; for it is evident that the greater its tension, it will cause the axes of the pulleys to press the more against their bearings, and thus increase the friction of the machine. When the two parts of the band are made to cross each other, as in fig. 38, it works with less tension, owing to its embracing a larger arc of each drum. There is thus some economy of power in this arrangement; besides that, it serves another purpose—namely, that of reversing the direction of the rotation.

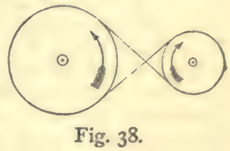


Fig. 38.

Toothed-wheels.—If the two pulleys or drums in fig. 38 were near enough to touch each other, by making the one revolve, the other would be made to revolve with it. This method of communicating motion serves only when the resistance to the driven pulley is very slight. The usual and sure method is to raise projections or *teeth* on the pulleys; this contrivance is called *toothed-gearing.*

Let C and C′ (fig. 39) be the centres of two toothed-wheels in gearing with each other (the centres are not represented in their actual positions, in order to save space). The line CC′ is called *the line of centres;* and the two circles, *gg, hh,* which touch each other in T, midway between the extreme projections of the teeth, are the *pitch circles.* The *pitch* of the teeth of a wheel is the distance, AB, from the centre of one tooth to the centre of the next, measured upon the pitch circle; and it is evident that for two wheels to work together, the pitch must be the same in both—that is, AB must be equal to TD. The breadth of the teeth is made a little less than the intervals between them, that they may have room to engage and separate without becoming locked in consequence of any slight irregularity.

The actual size of the wheels is not indicated by their solid rims or bosses, *ee, ff,* but by the pitch circles, *gg, hh;* and we shall best understand what is necessary to the true working of

toothed-wheels, if we conceive these circles to be, in the first instance, two drums touching at T,

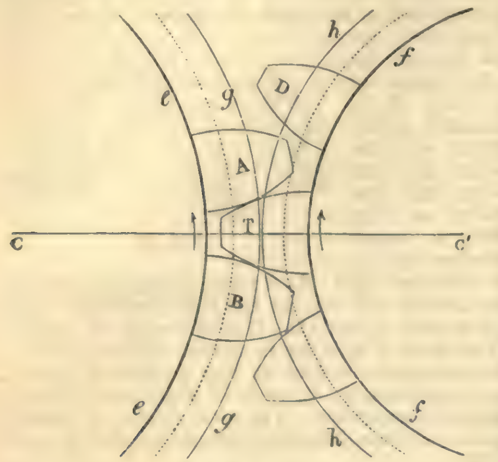


Fig. 39.

and the one driving the other by friction. It is obvious that while any portion, as a foot, of the drum *hk*—supposing it to be the driver—passes through the point of contact T, it causes an equal portion of the driven drum, *gg*, to pass through the same point; in other words, the driven circumference moves with the same velocity at every instant as the driving one. Now, when a part of the width of each wheel is removed, and projecting teeth substituted, these teeth must be so contrived that the primitive or pitch circles shall still move exactly as if they were in contact. Mere straight pegs or blades, like the paddle-boards of a steam-boat, would not answer the purpose. In the first place, the corners of one tooth would have to slide along the face of another, thus grinding away the teeth, and wasting the driving-power. Secondly, the motion would not be equal; during the first portion of the time that two teeth were in contact the driven wheel would move slower than the driver, and during the last portion, faster. The faces or edges of the teeth must, therefore, be curved, so that they shall roll on one another rather than slide; and the curves must be such that the driven wheel shall move at all times uniformly with the driver.

Mathematicians have discovered a great variety of ways of satisfying this condition. One way, frequently adopted, is to give the teeth of one wheel the form of the curve called the epicycloid, and those of the other that of the hypocycloid. But the form of teeth that possesses the greatest number of advantages for most purposes is that of the curve called the *involute*.

CHANGES IN THE PLANE AND IN THE DIRECTION OF ROTATION.

When the two shafts to be connected are not parallel to each other, conical or *bevel* wheels are employed. Fig. 40 represents a horizontal shaft driving a vertical one (or the converse), by means of bevel gearing. The two shafts may have any inclination to each other and to the horizon. When the two wheels are equal and the axes at right angles, they are called *mitre*-wheels. A *crown-wheel*, A, and *trundle*, B, as represented

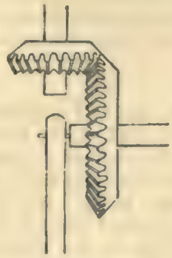


Fig. 40.

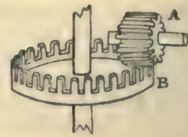


Fig. 41.

in fig. 41, is another contrivance for effecting the same purpose.

In the case of two toothed - wheels, the direction of the rotation is always reversed, as shewn by the arrows in fig. 39. In order to preserve the same direction in both, wheels are sometimes geared internally, fig. 42. By interposing a third wheel between the driving and driven wheels, the original direction is also retained; thus, the pinion F, fig. 43, revolves in the same direction as the wheel C. A crossed band (see fig. 38) reverses the direction.

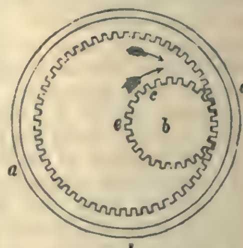


Fig. 42.

CHANGES IN SPEED.

If the wheel C, fig. 43, had three times as many teeth as the pinion G, one revolution of C would evidently cause three revolutions of G. If, instead of being an exact multiple, the teeth of C were, say 210, and those of G 90, which is in the proportion of 7 to 3, then 3 revolutions of C would cause 7 of G. Suppose, again, that C with 101 teeth were driving B with 100 teeth. These numbers being prime to one another, the proportion is not expressible in any smaller numbers than the numbers of the teeth themselves; in other words, if we note the two teeth that are at any instant in contact, C must make 100 revolutions, causing B to make 101, before the same two teeth will be again in contact—that is, before the two will finish together, each an exact number of revolutions.

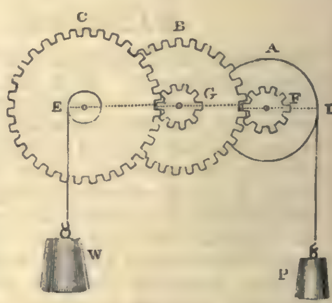


Fig. 43.

In a train of wheels connected, as in fig. 43, the velocity of the last wheel is found by the following rule: Multiply the velocity (or number of revolutions in a given time) of the first driver by the

product of the numbers of teeth in all the drivers, and divide the result by the product of the numbers of teeth in all the followers. In this rule, the diameters, or the radii, or the circumferences, of the wheels may be substituted for the numbers of the teeth.

Sometimes it is desirable to vary the speed of a part of a machine at different parts of a process, while the driving-power continues the same. One way of effecting this is by conical pulleys or drums, as in the fig. 44. According as the band is shifted along from one end to the other—and this the machine is made to do itself—the relative speed of the two pulleys will vary to the desired degree.

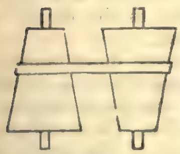


Fig. 44.

CHANGE OF ONE KIND OF MOTION INTO ANOTHER.

By means of a rack, *b*, and pinion, *a* (fig. 45), a rotary motion is converted into motion in a straight line. Both motions in this arrangement are necessarily alternating.

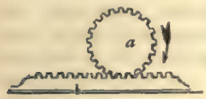


Fig. 45.

Fig. 46 represents a continuous rotary motion converted into an alternate rising and falling. The projections, called *cams* or *wipers*, of the wheel W, depress the end of the lever bearing the hammer, H, so that it is made to rise and descend on the anvil A thrice during each revolution of the wheel. The stampers of fulling-mills, and those used for crushing oil-seeds and other substances, are in a similar way lifted and dropped by the wipers of a wheel coming in contact with a pin projecting from the stamper.

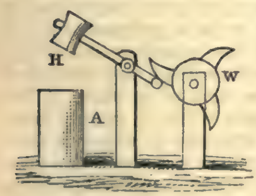


Fig. 46.

For converting an alternating straight motion into a continuous revolution, the most common means is the *crank*. A crank is an arm or bend on an axle or shaft. In the figure, the shaft extends on both sides of the bend, so that two wheels could be turned, and the motion is communicated by a connecting rod, S. If the portion to the left of the rod were removed, the arrangement would be what is called a winch, and might be driven by the hand.

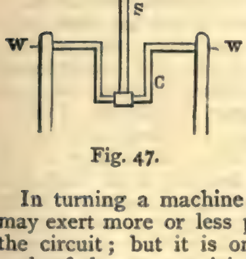


Fig. 47.

In turning a machine with a winch, the hand may exert more or less pressure at every point of the circuit; but it is only about the middle of each of the two semicircles, while the handle is being pulled towards the body, and again while it is being pushed away, that the full strength of the arms is effective. In a crank worked by a rod, there are two positions in which the effect of the pressure of the rod is reduced to nothing—namely, when the crank-arm C is in the same straight line, upwards or downwards, with the rod S. A push or pull of the rod in these positions can only press the shaft against its bearings. The effect is greatest when the rod and crank-arm are at right angles, and it decreases gradually on both sides of that position, until at the top and bottom it is reduced to nothing. In order to carry the crank over these *dead points*, as they are called, a heavy wheel, called a *fly-wheel*, is fixed on the shaft; this receives part of the force of the rod while at its best, acts as a reservoir, and by its stored-up energy carries the shaft round when the rod is powerless.

In marine-engines and in locomotives, a fly-wheel is unnecessary, and would be objectionable, owing to its weight and the room it requires. In these cases, the power is generally applied to the shaft at two points by two connecting rods, each proceeding from a separate cylinder; and the two cranks or bends of the shaft are made at right angles to one another, so that while the one is at one of its dead points, the other is at one of its best positions.

The crank can effect the converse of the change now described—that is, the conversion of a rotary motion into an alternating rectilinear one. But it is more usual, when an alternating motion of only small power is required, to take it from a revolving shaft by means of an *eccentric*. One of the most simple and elegant contrivances for converting motion in a curve into motion in a straight line is the *Parallel Motion*, invented by Watt.

FRICTION.

When one body rubs against another as it moves, a certain force is felt to resist the motion. This resistance is called *friction*. As a considerable proportion of the motive-power in all operations is spent in overcoming the friction of the parts of the machine upon one another, and is thus lost for the useful work, it is of great importance to understand the nature of this obstructive force, with a view to reduce it to the least possible amount. Accordingly, a great many careful experiments have been made on this subject, and the result is a number of precise and valuable facts or laws regarding friction, which are now considered certain and reliable. The more important may be thus stated and illustrated.

When a block of oak—say, a cubic foot, which weighs about 60 lbs.—is placed on a horizontal table of cast-iron, the two surfaces being flat and smooth, it requires a force of nearly ⅖ the weight of the block, or 24 lbs. pulling horizontally, to make it slide along the table. This measures the friction between the two surfaces. Another block of the same size and shape laid on the same table, would require the same force to draw it; and if the two were laid side by side, and fastened together so as to become one block, it would evidently require double the force, or 48 lbs. to draw the double block; the amount of the friction being thus still ⅖ of the weight, or of the pressure between the two surfaces. But suppose that, instead of being laid side by side, the second block were laid on the top of the first, what is to be expected?

Here the weight is doubled as before, but the extent of rubbing surface remains unaltered; it would be natural, therefore, to expect that this would make a difference, and that, though the friction would, of course, be increased, the increase would be less than in the former case. Experiment, however, shews that there is no difference, and that the friction is just double in both cases. In short, the unexpected and important fact is established, that, *within certain limits, the friction of any two surfaces increases in proportion to the force with which they are pressed together, and is wholly independent of the extent of the surfaces in contact.*

The amount of friction between two bodies is thus a constant fraction or proportion of the force with which they are pressed against each other. This fraction differs for the different kinds of surfaces. Thus between oak and cast-iron, it is, as already stated, about $\frac{3}{8}$, or more exactly, ·38; for wrought-iron on wrought-iron (we speak at present of dry surfaces, without grease or unguent of any kind), it is ·44; for brass upon cast-iron, ·22. This constant fraction (expressing the proportion between the pressure of two surfaces and their friction) is called the *coefficient of friction* for these two surfaces.

Friction is very much diminished by the use of grease or unguents. The coefficient of wrought-iron upon oak, which, in the dry state, is ·49, is reduced by the application of water to ·26, and by dry soap to ·21. The result of experiments on this subject is stated to be, 'that with the unguents, hog's-lard and olive-oil, interposed in a continuous stratum between them, surfaces of wood on metal, wood on wood, metal on wood, and metal on metal (when in motion), have all of them very nearly the same coefficient of friction, the value of that coefficient being in all cases included between ·07 and ·08.' Tallow gives the same coefficient as the other unguents, except in the case of metals upon metals, in which the coefficient rises to ·10.

The most important fact, perhaps, and one that could hardly have been anticipated before experiment, is, *that the friction of motion is wholly independent of the velocity of the motion.*

The resistance to the motion of a wheeled carriage proceeds from two sources: the friction of the axle, and the inequalities of the road. The resistance of friction to the turning of a shaft in its bearings, or of an axle in its box, has evidently the greater leverage, the thicker the journal or the axle is; the axles of wheels are accordingly made as small as is consistent with the required strength. The resistance that occurs between the circumference of the wheel and the road, constitutes what is called *rolling* friction. There are on all roads, to a greater or less extent, visible rigid prominences, such as small stones, in passing over which the wheel and the load resting on it have to be lifted up against gravity. But even were these wanting, the hardest road yields, and allows the wheel to sink to a certain depth below its surface; so that in front of the wheel there is always an eminence or obstacle, which it is at every instant surmounting and crushing down. This is the case even on iron rails, though of course to a much less extent than on any other road. Now, for overcoming this resistance, it can be shewn on the principle of the lever that a large wheel has the advantage over a small one; and by numerous experiments, the fact has been fully established, that on horizontal roads of uniform quality and material, *the traction varies directly as the load, and inversely as the radius of the wheel.*

The best direction of traction in a two-wheeled carriage, is not parallel to the road, but at a slight inclination upward, in proportion to the depth to which the wheel sinks in the road.

On a perfectly good and level macadamised road, the traction of a cart is found to be $\frac{1}{30}$ of the load; that is, to draw a ton, the horse requires to pull with a force equal to 75 lbs. On a railway, the traction is reduced to $\frac{1}{280}$ of the load, or to 8 lbs. per ton. For the addition to traction occasioned by an incline on the road, see page 215.

The force of friction is often directly employed in mechanics. It is used, for instance, to communicate motion by means of belts, chains, &c. It is the force that holds a knot. It is specially useful when a machine, with great momentum, has to be checked or arrested in its motion. The best example of this is the ***brake*** used on railways. By means of a system of levers, blocks of wood are made to press against the circumferences of a number of the carriage-wheels; and thus the momentum of a train weighing hundreds of tons, and moving with a velocity of perhaps 50 miles an hour, is gradually destroyed in a wonderfully short space of time.

WORK.

Work, in the mechanical sense, implies two things; it implies that something is moved, and that force or pressure is required to move it. In other words, all mechanical work involves the exertion of a continuous pressure over more or less space. To bear or resist a pressure without motion is not work. A man standing still with a burden on his back is not working, any more than a post that sustains the end of a beam. The hand, fig. 1, does no work while it merely holds the weight suspended, although it requires force to do so; for a fixed catch or pin above the lever would do the same. But when the upward pressure of the lever is overcome by the hand through the space PP′, a certain amount of work is done. Nor does motion, where there is no resistance, constitute work. While a cannon-ball is flying through the air, it is doing no work (if we neglect the resistance of the air that is overcome); it only works when it forces its way through an obstacle, as the planks of a ship's side.

The Unit of Work.—When one man lifts six gallons of water from a well twenty feet deep, while another lifts eighteen gallons from the same well; it is easy to see that the one has done three times as much work as the other. But in order that we may compare exactly the quantities of work in operations of different kinds, we must have some common standard to refer to. Just as, in comparing the height of a mountain with a distance on a road, we take a standard or unit of length, say a foot, and, applying it to both, find that the height of the mountain contains 800 of the unit, and the length of the road 900, and thus get a precise knowledge of their relative magnitudes; so it is necessary to have a *unit of work*, and thus be able to say of different operations, that they contain each so many of such units.

The unit of work adopted in this country is the amount of exertion necessary to overcome a pressure of one pound through a space of a foot. Thus, a hand does a unit of work when it lifts a pound-weight a foot high; or when it pulls in a foot of the cord of a pulley, the tension of which is equal to a pound-weight; or when it pushes with the force of a pound against the lever of a capstan, while the point against which it presses moves through a foot. It follows that the amount of units of work expended in any exertion of lifting, pushing, or pulling, is found by multiplying the number of pounds in the pressure by the number of feet through which it is exerted. 10 lbs. of coal lifted 10 feet high is the same amount of work, namely, 100 units, whether it is done in five seconds or in fifty. But when we consider the capacity of the agent for work, we require to take the time into account. An agent or worker that does 100 units of work in one second, has four times the working-power of an agent that requires four seconds to do 100 units. As a standard of capacity for work, the power of a horse is taken. From a number of experiments, Watt, the improver of the steam-engine, estimated that a horse, on an average, could do 33,000 units of work in one minute; that is, could lift 33,000 lbs. 1 foot high in 1 minute; and this has been generally assumed as the standard of working-power in all mechanical agents. When a steam-engine, for example, is said to be of 60 horse-power, the meaning is, that it is capable of lifting 60 times 33,000 lbs. or 1,980,000 lbs. 1 foot high in 1 minute; or, which is the same thing, 19,800 lbs. 100 feet high in 1 minute.

Ex. How many horse-power does it require to lift 1 ton of coals every five minutes from a pit 1000 feet deep? $2240 \times 1000 = 2,240,000$, the work to be done in 5 minutes. $2,240,000 \div 5 = 448,000$, the work to be done in 1 minute. $\therefore 448,000 \div 33,000$ (the work in one H. P.) $= 13{\cdot}6$, the number of H. P. required.

Work Accumulated in Moving Bodies.

A heavy body in motion is capable of moving other bodies. The force exerted to put it in motion is all treasured up in it, and ready to be exerted on any obstacle that may oppose it. In other words, a moving body has accumulated in it a power of doing the same amount of work as was done upon it, abating what may have been lost by friction or other obstacles; and if we know the velocity of a moving body and its weight, we are able to calculate how many units of work have been done upon it, and, therefore, how much work it is capable of doing.

The velocity being given in feet per second, and the weight in pounds, the rule of calculation is as follows: *Square the velocity, multiply by the weight, and divide by* $2 \times 32\frac{1}{6}$, *or* $64\frac{1}{3}$.

The reason of the rule may be thus shewn: When a body begins to fall from a state of rest, it descends $16\frac{1}{12}$ feet in the first second, and it has then acquired a velocity which, were gravity to cease, would carry it on uniformly over $2 \times 16\frac{1}{12}$, or $32\frac{1}{6}$ feet per second. The spaces descended increase as the squares of the times—that is, in 2 seconds the fall is 4 times $16\frac{1}{12}$ feet; in 3 seconds, 9 times $16\frac{1}{12}$. The velocities, again, increase simply as the times—that is, at the end of 2 seconds the velocity is 2 times $32\frac{1}{6}$ feet; of 3 seconds, 3 times $32\frac{1}{6}$. Putting h for the height or space fallen through in any number of seconds, v for the velocity at the end of that time, t the number of seconds, and g for $32\frac{1}{6}$, the velocity caused by gravity in one second, the relations of these quantities are expressed in the following formulas, which enable us to calculate any one of them from the others.

$h = 16\frac{1}{12} \times t^2$, or (1.) $h = \frac{1}{2}g \times t^2$; (2.) $v = g \times t$, and $\therefore\ t = \frac{v}{g}$, and (3.) $t^2 = \frac{v^2}{g^2}$.

If, in formula (1.), we substitute for t^2 its value in (3.)—namely, $\frac{v^2}{g^2}$, we get $h = \frac{1}{2}g \times \frac{v^2}{g^2}$, or (4.) $h = \frac{v^2}{2g}$.

Knowing the velocity of a falling body, then, we can find the space through which it must have fallen in order to acquire it, by squaring the velocity and dividing by $2 \times 32\frac{1}{6}$. The height thus found is said to be the height *due* to that velocity.

A falling body is urged by a pressure equal to its own weight; and, during a second, that pressure acts upon it over $16\frac{1}{12}$ feet. Therefore, if the body is a pound in weight, gravity has done upon it in that time $16\frac{1}{12}$ units of work; and if it is 10 lbs., the work done is $160\frac{10}{12}$ units. In other words, the work done upon a falling body, and therefore the work accumulated in it, is equal to the space through which it has fallen multiplied by its weight. We may not know that space, but if we know the velocity, we can substitute for it its value, $\frac{v^2}{2g}$.

Now, a cannon-ball, moving with a given velocity, has the same force, whether it acquired that velocity by falling from a certain height, or by being shot from a cannon; and the same rule that enables us to calculate the units of work in it in the former case, applies also in the latter. Calling e the accumulated work, and w the weight of the body, the rule given above may be expressed in a formula, thus: $e = \frac{v^2 \times w}{2g}$.

The expression $\frac{v^2 \times w}{2g}$, or $\frac{w}{2} \times \frac{v^2}{g}$, is what was formerly called the *vis viva* (living force) of a moving body, but is now spoken of as its *energy*.

Ex. 1.—A ram, weighing 5 cwt. or 560 lbs. as it strikes the top of a pile, has a velocity of 70 feet; what is the work accumulated in it?

$$\frac{70^2 \times 560}{2 \times 32\frac{1}{6}} = 42,653 \text{ units of work.}$$

Or we might proceed thus: The height from which the ram must have fallen to acquire the velocity of 70 feet, is $\frac{70^2}{2 \times 32\frac{1}{6}} = 76{\cdot}166$ feet. To raise the ram to this height required $76{\cdot}166 \times 560 = 42,653$ units of work done upon it, and this work it is capable of reproducing by its fall.

Ex. 2.—A train weighing 100 tons has a velocity of 50 feet a second, how far will it run before stopping after the steam is shut off, supposing the friction to be 8 lbs. per ton, and that the train is ascending an incline of 1 in 100?

$\frac{50^2 \times 224,000}{2 \times 32\frac{1}{6}} = 8,704,663$, the work accumulated in the train. Now, the resistance of friction is $8 \times 100 = 800$ lbs. and the resistance of the incline is $\frac{1}{100}$ of the whole weight, or 2240 lbs. making together 3040 lbs. To overcome this resistance over 1 foot makes 3040 units of work,

which is to be taken out of the store accumulated in the train; for how many feet, then, will that store last? Evidently for $\frac{8,704,663}{3040} = 2863$ feet.

Of the moving-power applied to a machine, only part goes to do useful work; another part is expended uselessly in overcoming the friction of the machine, and other resistances to its transmission. For every 100 units of work applied to the handle of a crane, possibly only 70 are done upon the load. In this case, the fraction $\frac{70}{100}$, or ·7, expresses the *efficiency* of the machine, and is sometimes called its *modulus*. The working values of different machines may thus be exactly compared. Of machines, for instance, for raising water, the modulus of the bucket-wheel is ·6, and that of the Archimedean screw, ·7.

SOURCES OF POWER.

The principal moving forces are, the muscular power of men and animals; the weight of bodies, or gravity; wind, and the flow of streams; the expansive force of steam; electricity; and magnetism. Water, steam, and electricity, as sources of moving power, are treated of in other parts of the work. The labouring-power of animals varies greatly with the way or position in which they exert their muscular strength. In turning a handle or winch, the pressure exerted at different parts of the circuit is very different; but it has been found that a man can exert for a considerable time a mean pressure of 30 lbs. while moving the handle through 120 feet per minute. This would give 3600 units of work a minute, or about $\frac{1}{9}$ of a horse-power. Another estimate of labour of this kind, when continued for eight hours a day, makes the work per minute only 2600, or $\frac{1}{13}$ of a horse-power. Rowing is one of the most advantageous ways of exerting muscular strength, the effective work being 4000. In working at the tread-mill the man exerts his strength to raise his own body, and the weight of the body in descending turns the wheel. The work got in this manner is 3900.

ENERGY.

A moving body, as we have seen, has in it a store of force called Energy, and the exact amount of this store can be stated in the number of foot-pounds of work it can do before being brought to a stand. But this is not the only form in which energy exists. A ram suspended ten feet above the head of a pile has in it, while yet at rest, a store of working power in virtue of its position; and it requires only to be let go in order to bring that power into action. While resting on the head of the pile after the impact, it has no working power, if we except the pressure of its own weight. It must be again raised so as to have a free space to fall, and then it is invested anew with energy equal in amount to what has been spent in raising it. A store of force thus quiescent, but capable of being called into action, is called *potential* energy; while that which exists in a body in motion is called *actual* or *kinetic* (from a Greek word signifying to move) energy. A ram descending upon a pile, a cannon-ball flying towards its mark, a running stream driving an undershot wheel, the wind pressing a sail, all are examples of actual or kinetic energy. As examples of potential energy that can be directly used for mechanical purposes, we may cite a coiled watch-spring, a drawn bow, the charged receiver of an air-gun, a store of water with a fall or head. In a common clock we see the potential energy of the wound-up weights gradually converted into actual energy in the motions of the parts. The very sound of the bell is a vibratory motion derived from the energy of the driving weight.

Correlation of Physical Forces.—In treating of HEAT (see No. 13), it was shewn that mechanical motion could be converted into heat, which is itself a motion among the molecules of bodies, and therefore a form of energy. The latent heat of steam is a store of potential energy, which, in the steam-engine, is converted into mechanical power. If that power is made to drive a shaft, and a brake is applied, heat to any amount may be reproduced; or if it is made to turn a common electric machine, or a magneto-electric one, electric currents will result, attended with attractions causing sensible motions, and with heat and light. Light, again, causes chemical combinations and decompositions, as in photography; and chemical action in the voltaic battery gives rise in its turn to electricity, heat, light, and magnetism. It is facts like these, shewing the convertibility of one force into another or into others, that constitute what is called the Correlation of Physical Forces.

Conservation of Energy.—But there is something more than mere convertibility in the different forms of energy; there is constant equivalence. If, in rubbing two pieces of wood against each other, energy has been expended equal to that of lifting a pound-weight 722 feet high, the heat produced is sufficient to raise a pound of water one degree of F. This relation is constant, and 722 foot-pounds is thus the mechanical equivalent of one unit of heat. The equivalents of the other physical forces have not been determined, although an approximation has been made in the case of light. But everything tends to prove that whatever transformations energy may undergo, none of it is ever lost. In every machine it is only a portion, greater or less, of the motive power that is effective for the work intended. But the residue, though said to be lost, so far as useful work is concerned, is not annihilated; it is mostly expended in overcoming the friction of the machinery, and in doing so it is transformed into heat. A part of it is spent in noise, but this also, in the end, results in heat, which is still energy. Energy, in the shape of heat, has a constant tendency to uniform diffusion; but although it thus becomes dissipated, it does not cease to exist. This truth has become the cardinal principle of natural philosophy in recent times under the name of the *conservation of energy;* and nearly all the ordinary physical laws can be shewn to be involved in it. Thus a planet has a certain amount of potential energy in virtue of its distance from the sun, just as a stone has when suspended above the surface of the earth. That energy must therefore become less as the planet moves from its aphelion towards its perihelion; what then becomes of it? The difference appears in the increased velocity of the planet, being thus transformed from potential energy into actual. Numerous illustrations of this important doctrine will occur in the treatises on ELECTRICITY and the STEAM-ENGINE.

HYDROSTATICS—HYDRODYNAMICS—PNEUMATICS.

THE properties of matter treated of under MECHANICS are such as arise chiefly from the *solid* state of bodies. But consequences scarcely less important arise from the other two states in which matter presents itself—from the *liquid* condition, as in the case of water, and the *gaseous* or aëriform condition, as in the case of air; and these form the subjects of the present treatise. The nature of the difference between these three states of matter is considered in the number on NATURAL PHILOSOPHY.

Liquids and gases agree in this, that their particles seem at liberty to glide about among one another, seemingly without resistance; they *flow*, and hence both classes of bodies are called *fluids*. There are very different degrees of fluidity. Some fluids are thick and viscid; such as tar, honey, and some metals in a state of fusion. Viscid fluids are, in general, not homogeneous; they consist of solid granules floating in a real fluid. Alcohol and ether are more fluid than even water. The most perfect fluidity belongs to the gases.

But what chiefly distinguishes gases from liquids is elasticity. A cubic foot of any gas may readily be compressed into half a foot; double the pressure will reduce it to a quarter of a foot; and when the pressure is removed, the gas returns to its original bulk. But no ordinary pressure produces any sensible compression on water or any other liquid. Hence gases have been denominated *elastic fluids*, and liquids, *non-elastic*. It is on account of this difference that the mechanical properties of the two classes of fluids are treated of apart.

We have said that liquids cannot be sensibly compressed by any ordinary force; and this is so far true, that both in the theory of hydrostatics and in practice they are assumed to be perfectly incompressible. But the assumption is not absolutely correct. They are slightly compressible under great pressure. By sinking a vessel in the ocean to the depth of 6000 feet, where every square inch supports a weight of 2648 pounds, it is found that twenty cubic inches of water contained in the vessel are reduced to nineteen cubic inches, or the volume of water is diminished by one-twentieth. A pressure equal to that of the atmosphere, or fifteen pounds on the square inch, reduces a million cubic inches of water to forty-five or fifty inches less.

The phenomena of liquids are considered under two heads, according as the pressures to which the liquids are subjected produce rest or motion. The laws of liquids at rest or in equilibrium form the subject of *Hydrostatics* (from two Greek words signifying *water* and to *stand*); those of liquids in motion form the subject of *Hydrodynamics* (from the Greek words for *water* and *power*). *Hydraulics* is sometimes used in the same sense as Hydrodynamics, but has more especial reference to the flow of water in *pipes* (Gr. *aulos*).

HYDROSTATICS.

In treating of the mechanical properties of liquids, water, as the most common and important, is taken to represent the whole class.

It is the perfect *mobility* of the particles of liquids that gives them the mechanical properties considered in Hydrostatics. The fundamental property may be thus stated: WHEN A PRESSURE IS EXERTED ON ANY PART OF THE SURFACE OF A LIQUID, THAT PRESSURE IS TRANSMITTED UNDIMINISHED TO ALL PARTS OF THE MASS, AND IN ALL DIRECTIONS. Most of the other propositions of Hydrostatics are only different forms or direct consequences of this truth.

The proposition may be experimentally proved in a variety of ways. If, for instance, a bladder is filled with water, and tied, and then pressed down with one hand; the other hand, if applied to the bladder, will be pushed out with corresponding force, and that whether resting on the top, the sides, or under. Suppose, again, a close box, B, filled with water, and having a tube, *a*, inserted into the upper cover, of an inch in area, and with a plug or piston fitting into it. If the piston *a* is now pressed down upon the water with a force equal to a poundweight, the water, being unable to escape, will react upon the piston with the same force; but it obviously will not press more against *a* than against any other part of the box, therefore every square inch of the interior surface of the box is pressed outward with the force of a pound. If, then, there is another tube inserted in any part of the box with a plug of the same area, as at *b*, it will require a force of a pound to keep this plug in its place. (We leave out of account at present the pressure upon *b* arising from the *weight* of the water in the box above it, and consider only the pressure propagated by the forcing down of the plug *a*.) However many plugs of the same size there were, each would be pressed out with the same force of a pound; and if there were a large plug of four times the area, as at *c*, it would be pressed out with a force of four pounds.

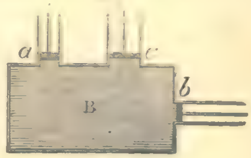


Fig. 1.

We have only, then, to enlarge the area of the piston *c* to obtain any multiplication of the force exerted at *a*. If the area of *c* is 1000 inches, that of *a* being one inch, a pressure of one pound on *a* becomes a pressure of 1000 pounds on *c*; and if we make the pressure on *a* one ton, that on *c* will be 1000 tons. This seemingly wonderful multiplication of power has received the name of the *hydrostatic paradox*. It is, however, nothing more than what takes place in the lever, when one pound on the long arm is

made to balance one hundred pounds on the short arm. When we think of the machine in motion, we see that what is gained in power is lost in time. If the piston in *a* descend one inch, it will raise the piston *c* only the one-thousandth part of an inch; for a descent of one inch in *a* dislodges a cubic inch of water, forcing it into the box; this causes a cubic inch of water to rise into *c*, where it is spread out over a thousand times as much surface, and therefore has only the thousandth part of the depth.

If the pressure we have supposed exerted on the piston *a* arose from a pound of water poured into the tube above it, it would continue the same though the piston were removed. The pound of water in the tube is then pressing with its whole weight on every square inch of the inner surface of the box—downwards, sidewise, and upwards—and, if the box is twenty inches each way, so as to have upwards of 2000 inches of surface, this one pound of water is tending to burst it with a force of about half a ton. That this is no mere theory, may be proved without much difficulty, by fitting a long small tube, *b*, into the top of a cask, *a*, as represented in fig. 2. If the tube is only the twentieth of an inch in area, and is made long enough to contain a pound of water, it gives a bursting force of twenty pounds on every square

Fig. 2.

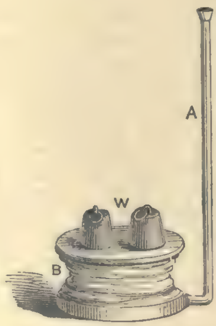


Fig. 3.

inch of the inner surface—a strain which no ordinary cask could resist.

The apparatus called the *hydrostatic bellows* acts on the same principle (see fig. 3). It consists of two stout circular boards connected together by leather in the manner of a bellows, B. The tube A is connected with the interior; and a person standing on the upper board, and pouring water into the tube, may lift himself up. If the area of the upper board is 1000 times that of the tube, an ounce of water in the tube will support 1000 ounces at W.

It is on the principle explained with regard to the two pistons, *a* and *c*, in fig. 1, that the very useful machine called the *Hydraulic Press*, invented by Bramah, is constructed. Fig. 4 represents the essential parts of the machine, the details of construction being omitted. F is the cavity of a strong metal cylinder, E, into which the piston D passes water-tight through the top. A tube, G, leads from the cylinder to a force-pump, H; and by means of this, water is driven from the tank T into the cavity F, so as to force the piston D upwards. The piston supports a table on which are placed the bales, books, or other articles to be pressed; and the rising of the table presses them against the entablature AA, which is fastened to the pillars B, B.

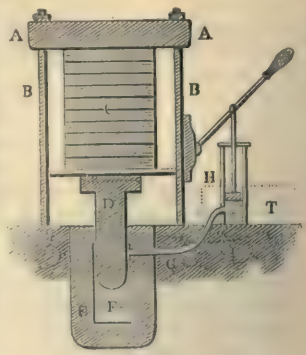


Fig. 4.

The power of the hydraulic press is readily calculated. Suppose that the pump has only one-thousandth of the area of F, and that, by means of its lever handle, the piston of the pump is pressed down with a force of 500 pounds, the piston of the barrel will rise with a force of one thousand times 500 pounds, or more than 200 tons. The rise, however, will be slow in proportion to the gain of power.

PRESSURE OF WATER ON SURFACES IN VARIOUS POSITIONS.

Water has weight like solids, and this weight produces pressure; but the quality by which it transmits pressure in all directions, makes its weight be felt in many respects differently from that of solids. Thus, suppose a cylindrical vessel filled with a piece of ice exactly fitting it; the whole weight of the ice will rest on the bottom, the sides being unaffected. But if the ice is now melted, the bottom will sustain the same weight as before, and the sides will at the same time be pressed outwards with a certain force. Any object immersed in water is also pressed on all parts of its surface in contact with the water. We have now to determine the amount of this pressure caused by the weight of water in various circumstances.

The pressure of water increases in intensity with the depth, without regard to the shape or size of the cavity or vessel containing it.

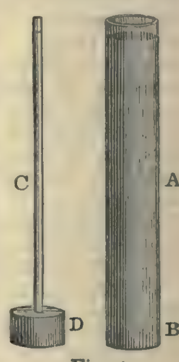


Fig. 5.

Suppose the water in the two vessels represented in fig. 5 to be divided into layers of an inch deep. If the area of the tube C is one square inch, and that of the larger cylinder, A, ten inches, the top layer in the tube will contain a cubic inch of water, and that in the cylinder ten cubic inches. Now, these layers rest on the surfaces of the layers below them; the second layer in the tube sustains the weight of a cubic inch of water; that in the cylinder, ten cubic inches. But in the last case the weight is equally distributed over ten square inches of surface; in both cases, then, the pressure on a square inch of the upper surface of the second layer is the weight of a cubic inch of water, or about 252 grains. In like manner, each

square inch of the surface of the third layer, in either vessel, has to bear the weight of two cubic inches of water, and the particles at that depth push upwards and laterally with corresponding intensity. The pressure thus increases with the depth equally in the narrow vessel and in the wide.

If we suppose the vessels to be each a foot deep, it is evident that on every square inch of the bottom of the cylinder there will rest a pile of twelve cubic inches (weighing about half a pound troy), and therefore the pressure on the whole bottom will be the weight of ten such columns. But from the shape of the other vessel, the lower part of which is enlarged, it is not so evident what the pressure on the bottom is. One thing is clear, that, on the square inch in the middle of the bottom immediately under the tube, there rests a column of twelve cubic inches. Now, there must be the same pressure among the particles of the water lying around the bottom of this column as among its own particles, otherwise there would be a flow towards the part where the pressure was less. Throughout the whole of the enlarged space D, there is the same pressure as there is at the same level immediately under the tube. Therefore, if the enlarged part of the vessel is of the same width as the cylinder, having an area of ten square inches, the pressure on the whole bottom is equal to the weight of ten times twelve cubic inches of water, exactly as in the cylinder at B.

It thus appears that *the pressure on the horizontal bottom of a vessel is as the area of the bottom and the perpendicular height of the liquid*, and that without regard to the shape of the vessel.

Take the case of two vessels of equal capacity, and shaped as in figs. 6 and 7. In fig. 6, the

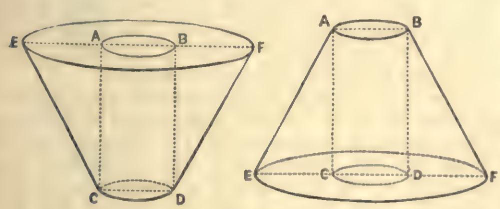


Fig. 6. Fig. 7.

bottom is pressed with the weight of the column of water ACDB. In fig. 7, the portion CD, equal to the whole base of the other, sustains an equal column; but from the law of liquids the same pressure is extended over the whole bottom. Now, if the diameter EF is three times the diameter CD, the larger bottom is nine times the area of the smaller. Therefore, the pressure on the bottom of fig. 7 is nine times the pressure on that of fig. 6, although both vessels contain the same quantity of water. If the bottoms of the vessels were separate from the sides, and kept in their places by springs or weights, it could be shewn experimentally that such is the case.

A strange consequence would seem to follow from this. If the two vessels in fig. 5 were placed on the opposite scales of a beam, the bottoms of both being equally pressed, it would seem as if they must balance each other. Similarly, we might expect fig. 7 to weigh nine times as much as fig. 6. But that such cannot be the case appears from the following considerations: In the upright cylinder in fig. 5, the lateral pressure being directly horizontal, neither presses the sides down upon the bottom nor lifts them up; but with the irregular vessel it is different. Where the small tube C enters the wide part D—say two inches from the bottom—the pressure of the column is equal to ten cubic inches of water on the square inch; and as this pressure acts upwards as well as downwards, the horizontal cover of the wide part is pressed *upwards* with a force of ten cubic inches on the square inch. Its area, the tube being one inch, is nine inches, so that the whole upward pressure is 9×10 cubic inches. The cover being attached to the sides, and the sides to the bottom, a part of the pressure on the bottom is thus counteracted, and only the difference—the difference between 10×12 and 9×10—or thirty cubic inches of water—remains to weigh down the scale. The confined water is in this case like a person in a covered box who should place his shoulders against the top and press against the bottom with his feet; he would thus add nothing to the weight of the box beyond his own dead weight. With regard to figs. 6 and 7, the pressure on the sides EC and ED of the former being at right angles to those sides, is partly downwards, and thus adds to the direct pressure on the bottom; while in fig. 7 the pressure on the sides is partly upwards, so as to relieve a part of the bottom pressure. The result is, that the pressure or weight on the scale is the same in both.

Pressure of Liquids on the Sides of Vessels.—We begin with the case of an upright side as the simplest. Let AB represent a vessel with upright rectangular sides filled with water, and suppose the perpendicular depth, AC, of the water to be six inches. A square inch of the bottom at C*d* is evidently pressed with the weight of a column of six cubic inches of water. Now, as water presses equally in all directions, the square inch from C to 5 of the side adjacent, will also be pressed; but evidently not to the same extent, owing to the gradual diminution of the weight of the water, as we advance upwards. The particle of water in the corner at C presses equally downwards and outwards, and as its pressure

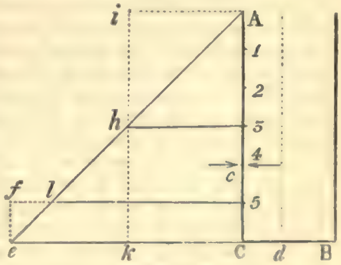


Fig. 8.

downwards arises from the weight of the column of particles above it from C to A, we may represent its outward pressure by the line C*e*, made equal to CA. At 5, the downward pressure, and therefore also the outward pressure, is one-sixth less, and will therefore be represented by 5*l*, made equal to 5A. If *el* is joined, the figure C*el*5 represents the sum of the outward pressures of all the particles from C to 5, and also the mode of their gradual diminution. Had the pressure continued constant, the sum would have been expressed by the parallelogram C*f*, which is equal to A*d*, the weight on the bottom. From this it

appears that the pressure on a square inch of the side next to the bottom is less than that on a square inch of the bottom itself, by the weight of half a cubic inch of water.

By similar reasoning, the pressure at any point on the side is represented by a horizontal line equal to the depth of the point from the surface, or the *head of water* of the point, as it is called. Thus, at 3, the pressure is $3h$, equal to 3A. Now, by the property of similar triangles, the extremities of all such lines, e, l, h, are in the same straight line with A; and by joining them, we have a triangle, CeA, representing the amount and mode of distribution of the lateral pressure on the side CA.

What is true of one vertical row of square inches in the side, is true of all the vertical rows of which it is composed; and therefore the pressure on the whole rectangular side is equal to the weight of a wedge-shaped mass of liquid, ACe, whose base is equal in area to that side. But the content of ACe is evidently equal to that of a uniform rectangular column of mean depth, $3h$. If, then, we suppose the length of the side to be 10 inches, its depth being 6 inches, the area will be 60 square inches; and this multiplied by 3, the mean depth, gives 180 cubic inches of water, the weight of which is equivalent to the lateral pressure. The truth thus arrived at may be expressed in the following general proposition: *The lateral pressure of a liquid, perpendicular to the side of a vessel, is equal to the weight of a column of the liquid whose base is the side and height equal to the depth of the middle point, or centre of gravity of the side.*

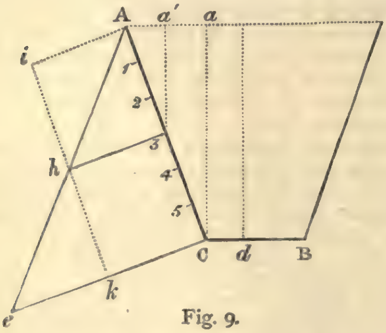


Fig. 9.

In the case of a vessel with a sloping side, AC (fig. 9), the pressure perpendicular to AC is still represented by a wedge-shaped mass, ACe; but here Ce is not equal to CA, but to Ca, the perpendicular depth of the water; and $3h$ to $3a'$, the mean perpendicular depth. In all cases, when speaking of depth or head of water, it is perpendicular depth that is meant.

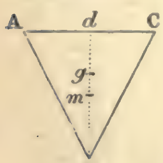


Fig. 10.

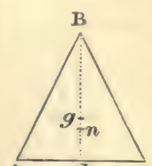


Fig. 11.

We have as yet considered only rectangular sides, in which the middle point, or point of mean pressure, lies midway between the surface and the bottom, or at half the depth. But in the case of a vessel with a triangular end or side, like ABC (fig. 10 or 11), it is evident that the middle point of the figure is not at m, the middle of the vertical line Bd. For in fig. 10 the number of points or units of surface that lie below m, and are therefore pressed with greater force, is far less than of those that lie above m, and sustain less pressure. The real middle point of any surface is its centre of gravity; and the centre of gravity of a triangular surface is found by drawing a line from any angle, B, to the middle of the opposite side, d, and taking the point g at one-third of the distance from d to B. The mean depth, then, or mean head of water, in fig. 10, is dg; and in fig. 11, Bg.

The pressure of a liquid on a surface is the same whether the surface forms part of the bottom or sides of the vessel containing the liquid, or belongs to a body immersed in the liquid. If an empty box, having for one of its sides a triangle like ABC, fig. 10, is sunk in water to any depth, the water will exert a pressure tending to force in the side, whether it be uppermost or undermost, vertical or oblique; and the amount of the pressure could be shewn, as in the cases already examined, to depend on the area of the surface and the depth of its centre of gravity from the surface of the water.

A cubic foot of pure water weighs very nearly 1000 oz. avoirdupois, or 62·5 lbs. More exactly, a cubic inch of distilled water, at the temperature of 62° F. and barometric pressure of 30 inches, weighs 252·46 grains; and a cubic foot weighs 62·32 lbs. or 997 oz. The cubic foot of sea-water may be taken on an average at 1026 oz. By means of these data, we can solve such a question as the following:

Required the pressure on a lock-gate 12 feet wide, the depth of the water being 10 feet? The area of the surface pressed is $12 \times 10 = 120$ square feet; 120 multiplied by 5 (the depth of the middle point of the surface) gives 600 cubic feet of water as the pressing column; and $600 \times 62{\cdot}5 = 37{,}500$ lbs. is the pressure in weight.

The circumstance of pressure increasing in proportion to depth, makes it necessary to increase the breadth of embankments for dams and canals from the top downwards; also to increase the strength of the lower hoops of large vats, to prevent their bursting. It likewise teaches the propriety of making dams, ponds, canals, and vessels for liquids generally, as shallow as is consistent with convenience or their required purpose. In every case, it is important to recollect that the degree of pressure on the sides is irrespective of shape or size of the contents, and depends exclusively on the perpendicular depth of the liquid.

When the poet speaks of 'the *broad* ocean leaning against the land,' we are apt to think of the broadness as adding to the weight that the land has to sustain. But the pressure against a square foot of the shore of the broad Atlantic is no greater than against a foot of the shore opposite Dover, or a foot of the side of a canal, at the same depth. The pressure against the gates of a canal is the same whether the next lock is a mile or whether it is 50 yards off. It might be brought within a foot, or even a fraction of an inch, and the weight on the gate would remain unchanged so long as the depth was the same. This being the case, it is really no more difficult to embank the calm ocean than a small lake of the same

depth; except for the violence of the waves, the same strength of dike would resist the weight in both cases.

At the depth of a foot, the pressure on a square inch of surface is a column of 12 cubic inches, weighing, in the case of fresh water, very nearly 7 oz.; and in the case of salt water, slightly more than 7 oz. This gives, at the depth of 7 feet, a pressure of 49 oz. or about 3 lbs. As water is so very slightly compressible, we may assume, without any great error, that its density is uniform at all depths, and, therefore, that the pressure will go on increasing regularly at the rate of 3 lbs. on the square inch for every 7 feet in depth. It is thus easy to calculate the pressure at any given depth. At a thousand feet, for instance, it will be $\frac{1000}{7} \times 3 = 428\cdot6$ lbs. or about 29 atmospheres. At the depth of a mile, or 5280 feet, it will be $\frac{5280}{7} \times 3 = 2263$ lbs. or 150 atmospheres.

Centre of Pressure.—We have seen that a vertical line or section AC (fig. 8) of a vessel containing a liquid, is pressed outwards by a set of forces increasing in intensity at every point from A to C. Now, there is evidently a point somewhere in AC at which, if a single pressure of sufficient strength is applied on the outside in the opposite direction, it will counteract the effect of all the outward pressures at the several points on the inside, and hold the line in its place. This point is called the *Centre of Pressure;* it is the point of application of the resultant of all the elementary pressures exerted at the different points.

As the pressures on the opposite sides of the centre of pressure must balance as on a fulcrum, it is clear that it cannot be on the middle of AC, but nearer the bottom, where the pressures are the greatest. And since the distribution of the pressure is represented by the triangular area AC*e* (fig. 8), the centre of pressure will be determined by that of the centre of gravity of the triangle; in other words, it will be at the point 4, which is ⅓ of the height of the triangle (see NATURAL PHILOSOPHY).

For surfaces of other forms than rectangular, the investigation of the centre of pressure is too difficult for introduction here. On a triangular side in the position of ABC (fig. 10), it is determined to be at *m*, ½ the depth; in the position of fig. 11, it is at *n*, ¼ from the bottom.

Each stave of a vat or cask may be considered as a rectangular side; the position, therefore, where a single hoop has the greatest effect in resisting the pressure, is at ⅓ from the bottom.

THE SURFACE OF LIQUIDS.

The surface of a mass of liquid at rest is a perfect level. Two or more points are on the same level when they are equally distant from the earth's centre. Let EAPBS represent a portion of the earth's circumference, C its centre, and L, T, two points above the surface equally distant from C; then L and T are on the same level; and if an arc of a circle is described from C through these two points, any other points, as Q, R, in that arc are on the same level with L and T. In like manner, the points A, P, B, in the earth's circumference, are on the same level; and so are *m* and *n*, below it. A level line, then, is, strictly speaking, not a straight line, but a portion of a circle; and similarly, a level surface is not a plane, but a portion of a spherical surface.

The direction of gravity—that is, the direction of a plumb-line—is always towards the earth's centre. Thus, at T or at B, the direction of

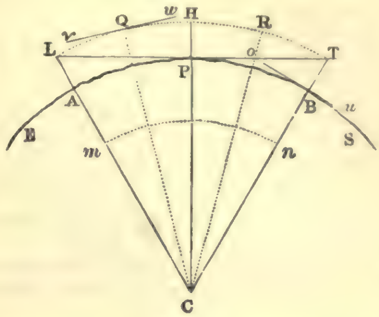


Fig. 12.

gravity is the line TBC; at Q, it is the line QC; and so of the other points in the figure. These lines marking the direction of gravity are perpendicular to the earth's surface, or to any other level surface, as LHT. A straight line, as TB, is perpendicular to a curve when it is perpendicular to the line B*u* drawn touching the curve at the point B. The lines TB, HP, LA, that mark the direction of gravity, are called *vertical* lines; and lines at right angles to them, such as *o*B*u*, LPT, *v*Q*w*, are *horizontal* lines.

When we confine our attention to a small arc of a very large circle, it does not differ sensibly from a straight line. Owing to this, 'horizontal' and 'level' are used, in common language, to signify the same thing. It is only when we take in a considerable space that the difference becomes appreciable. When considering a mass of water in a vessel or pond, then, the surface may be assumed to be straight or plane, and all vertical lines, or lines shewing the direction of gravity, as parallel to one another.

The familiar fact, that the surface of a liquid at rest is always level or horizontal—in the popular sense—admits of explanation; it can be shewn to be a consequence of the primary property of 'pressing equally in all directions.' For let *da* and *cb* be vertical lines, or lines in the direction of gravity; and *ab* a plane at right angles to that direction, or horizontal. A particle of the liquid at *a* is pressed by the column of particles above it from *a* to *d;* and the like is the case at *b*. Now, since the liquid is at rest, these pressures must be equal; for if the pressure at *b*, for instance, were greater than at *a*, there would be a flow of the water from *a* towards *b*. It follows that the line *ad* is equal to *bc*, and hence that *dc* is parallel to *ab*, and therefore horizontal. The same might be proved of any two points in the surface; therefore the whole is in the same horizontal plane. Or we might prove the same thing by the

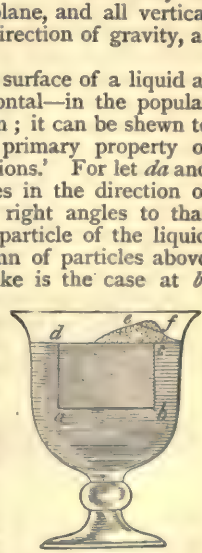


Fig. 13.

following consideration: if we could conceive a portion of the surface heaped up, as at *ef*; besides causing unequal pressure, and therefore disturbance in the mass below, the particles on the summit would have a tendency to flow down as on an inclined plane. Particles of sand so heaped up have this tendency; and are only prevented from spreading out into a perfectly level surface by their imperfect mobility.

It seems so natural that the surface of an unbroken mass of liquid should be all of one height, that we seldom think of it as requiring explanation. But when the surface of a liquid is not continuous, being contained in separate vessels, with communication between them, it requires consideration, and experience to convince us that the several parts of the surface must in all cases stand at the same level. A common tea-pot affords the most familiar illustration of this truth.

Fig. 14 represents six vessels communicating with one another, or rather one vessel consisting

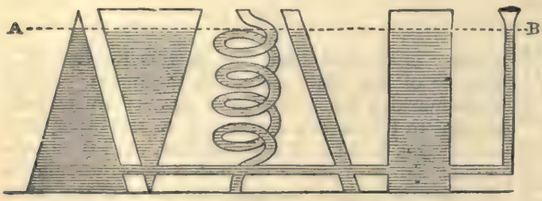


Fig. 14.

of six compartments of different shapes and sizes; and it can be shewn in the same way as with a continuous mass of water, that the surface in all the compartments must form part of the same horizontal line AB.

It is only when a sheet of water is stretched out to an extent of several miles that the convexity becomes conspicuous. It is very perceptible on the ocean when a ship is approaching on the horizon; first, the masts and sails of the ship are seen, and lastly, the hull. The convexity of the land is not so conspicuous, in consequence of the many risings and fallings in the surface. It is only in extensive plains that the roundness can be perceived in the same manner as at sea.

The amount of the earth's convexity can be calculated exactly. It is very nearly eight inches in each mile; that is, if PL (fig. 12) is a mile long, the point L will be eight inches above the surface.

In constructing canals and railways, allowance must be made for the convexity of the earth; for the channel of a canal, or a line of level railway, does not form a straight line, but a curve; it is not a part of the tangent or PL, but of the curve PA.

Levelling.—The most common instrument for determining levels is the *spirit-level.* It consists of a glass cylinder, *ac*, slightly convex on the upper side, and filled with spirits, all except a small space. It is placed for protection in a wooden or brass case, the bottom of which is exactly parallel with the tube. If the instrument is laid on the upper surface of a stone slab or a beam, and if one end of the slab or beam is higher than the other, the liquid in the tube will seek the lowest position, and the air-bubble will move towards the

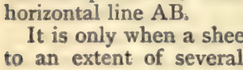


Fig. 15.

higher end; when the bubble rests in the middle, as at *b*, the surface is horizontal or level. To ascertain levels at a distance, the spirit-level is fixed below a small telescope, the tube of the telescope and the glass tube being made exactly parallel. The telescope being fixed on a stand, is adjusted by screws until the air-bubble of the spirit-level stands exactly in the middle, and is thus made perfectly horizontal. A pole being now set up at the spot where the level is to be found, the telescope is directed to it, and the point of the pole which appears in the centre of view is in a horizontal line with the eye. If the distance is short, this point may be considered as the level; but if the pole is as far as a mile off, the natural level at which water would stand, if there were a sheet of it all the way, will be eight inches below. The difference between the *apparent level* and the *true level*, as they are sometimes called, varies for different distances, and may either be calculated or taken from a table.

BUOYANCY AND FLOTATION.

When a solid is immersed in a liquid, it displaces exactly its own bulk of the liquid. This requires no demonstration; as soon as we conceive clearly what is meant, the truth of the proposition is self-evident. Of course, it is only of solids that are neither melted nor penetrated by the liquid that the proposition holds good.

If a cubic inch of wood or of a metal is wholly immersed in a vessel previously full of water, the liquid that occupied the space where the solid now is, must overflow; or, if the vessel was not full, the level of the liquid must rise. This affords a ready means of measuring solids, even the most irregular in shape. To ascertain what bulk of solid metal there is in a gold chain: have a cylindrical vessel with a base of known area—say a square inch—filled to a certain height with water; drop in the chain, and note the rise of the liquid. If it rise an inch, the chain contains a solid inch of gold, and so for any fraction of an inch. Archimedes is said to have been the first to think of measuring solid bodies in this way, and to have applied it in detecting the adulteration of a gold crown.

Every one must have experienced that a heavy body, held in the hand, becomes lighter when it is immersed in a liquid. We have now to consider how this loss of weight arises, and what is its amount.

Conceive, first, that a body of water, AB, forming part of the contents of a vessel, is separated from the rest by an imaginary film; this water will clearly remain suspended like any other portion of the mass. Now, as its weight is pressing it downwards, there must be an equal force acting upon it upwards. That force arises from the pressure of the surrounding liquid, which is acting upon it in all directions, upwards, downwards, and laterally. The horizontal pressures have each an opposite and equal resultant, and thus mutually destroy one another; but the under surface being at a greater depth than the upper, there remains a

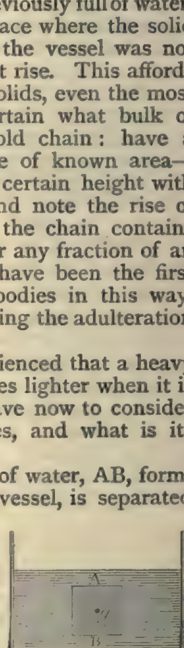


Fig. 16.

balance of upward pressure. This balance or result must be exactly equal to the weight of the conceived isolated body, otherwise it could not keep it at rest. The upward pressure, then, on any separate portion AB, say a cubic foot, within a mass of liquid, is equal to the weight of that portion. This is true, whatever be the shape of the isolated body. If we now suppose the mass of water, AB, to become solid ice without change of bulk, the same pressure will act upon it as before; and if we further conceive the cubic foot of ice to become a cubic foot of gold, the upward pressure upon it will remain the same—namely, the weight of a cubic foot of water, or the weight of the water it displaces. To this extent the water supports it, and renders it lighter.

It appears, then, that *a solid body in a liquid loses as much weight as an equal bulk of the liquid weighs.*

If a cubic foot of the liquid and of the solid have equal weights, the solid will lose all its weight, or will remain in the liquid wherever it is put; if a cubic foot of the liquid weigh more than one of the solid, the solid will not only lose all its weight, but will rise up, and that with a force equal to the difference; if a cubic foot of the liquid weigh less than one of the solid, the solid will lose weight, but will still sink.

It follows that, when two liquids, or, generally, when two fluids (for the principle is true of gases as well as of liquids) of different specific gravity are put together into the same vessel, the lighter will float on the top of the heavier, provided they are of a kind that do not intermix. For if we suppose AB (fig. 16) to be a mass of oil surrounded by water, being lighter than the same bulk of water, it must rise up; and as it cannot remain in a heap at the top, it diffuses itself in a horizontal stratum.

A body of alcohol or spirits in similar circumstances would take the same position for an instant; but the attraction existing between alcohol and water, soon causes a mutual and equal diffusion of the one through the other.

When a solid swims, or rises and *floats* on the surface of a liquid, the next problem of hydrostatics is to determine how much of it will be below the surface. We have already seen that any solid in a liquid is pressed upward with a force equal to the weight of the water whose room it occupies. Now, a floating body must be pressed up with a force equal to its own weight, otherwise it would sink lower; hence, *a floating body displaces its own weight of the liquid.*

By measuring how many cubic feet of water a floating body, such as a ship, displaces, we can thus know its weight, by allowing 1000 ounces, or 62·5 lbs. for every cubic foot.

As the buoyancy of a body thus depends on the relation between its weight and the weight of an equal bulk of the liquid, the same body will be more or less buoyant, according to the density of the liquid in which it is immersed. A piece of wood that sinks a foot in water, will sink barely an inch in mercury. Mercury buoys up even iron. Sea-water is denser than fresh water, in the proportion of 1026 to 1000. A ship, then, that carries 1026 tons on the sea, would carry only 1000 tons on a fresh-water lake.

The human body has almost the same weight as an equal bulk of water. When the lungs are full of air, it is slightly lighter, and will float with a bulk of about half the head above water. A person, then, that cannot swim, but has presence of mind to lie flat on the back, with the back part of the head submerged, may, by keeping the lungs full, continue to float with the face above water; but if any other part of the body, as a hand, is raised above the surface, the whole head goes immediately under. Swimmers, by the action of hands and feet against the water, keep the whole head, and often more, above the surface.

A body which would sink of itself, is buoyed up by attaching to it a lighter body; the bulk is thus increased without proportionally increasing the weight. This is the principle of life-preservers of all kinds. The most common are those which consist of pieces of cork, or other very light material, attached to the upper part of the body. But air-tight bags are preferable, as they may be said scarcely to encumber the body when empty, and, as danger approaches, they can be inflated with ease by being blown into. Life-boats have large quantities of cork in their structure, and also air-tight vessels made of thin metallic plates; so that, even when the boat is filled with water, a considerable portion of it still floats above the general surface. The bodies of some animals, as sea-fowl, and many other species of birds, are considerably lighter than water. The feathers with which they are covered add very much to their buoyancy. Fishes are enabled to alter their buoyancy by means of an air-bag, which they can inflate at pleasure by an apparatus for generating gases.

The buoyant property of liquids is independent of their depth or expanse, if there be only enough to surround the object. A few pounds of water might be made to bear up a body of a ton-weight; a ship floats as high in a small dock as in the ocean.

Stability of Floating Bodies.—Conceive *abd* (fig. 17) to be a portion of a liquid turned solid, but unchanged in bulk; it will evidently remain at rest, as if it were still liquid. Its weight may be represented by the force *cg*, acting on its centre of gravity *c*; but that force is balanced by the

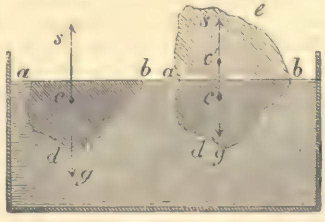


Fig. 17.

Fig. 18.

upward pressure of the water on the different parts of the under surface; therefore, the resultant of all these elementary pressures must be a force, *cs*, exactly equal and opposite to *cg*, and acting on the same point *c*, for if it acted on any other point, the body would not be at rest. Now, whatever other body of the same size and shape we suppose substituted for the mass of solid water *abd*, the supporting pressure or buoyancy of the water around it must be the same; hence we conclude, that *when a body is immersed in a liquid, the buoyant pressure is a force equal to the weight of the liquid displaced, and having its point of*

application in the centre of gravity of the space from which the liquid is displaced. This point may be called the *centre of buoyancy.*

We may suppose that the space *abd* is occupied by the immersed part of a floating body *aebd* (fig. 17). The supporting force, *cb*, is still the same as in the former case, and acts at *c*, the centre of gravity of the displaced water; the weight of the body must also be the same; but its point of application is now *c'*, the centre of gravity of the whole body. When the body is floating at rest or in a state of equilibrium, this point must evidently be in the same vertical line with *c*; for if the two forces were in the position of *cs*, *c'g* (fig. 18), they would tend to make the body roll over. The line passing through the centre of gravity of a floating body and the centre of gravity of the displaced water is called the *axis of flotation.*

The equilibrium of a floating body is said to be *stable*, when, on suffering a slight displacement, it tends to regain its original position. The conditions of stability will be understood from the accompanying figures. Fig. 19 represents a body

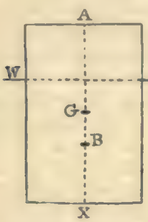


Fig. 19.

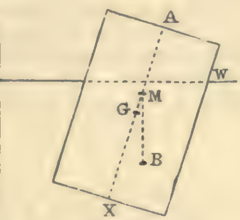


Fig. 20.

floating in equilibrium, G being its centre of gravity, B its centre of buoyancy, and AGB the axis of flotation, which is of course vertical. In fig. 20 the same body is represented as pushed or drawn slightly from the perpendicular. The shape of the immersed portion being now altered, the centre of buoyancy is no longer in the axis of the figure, but to one side, as at B. Now, it is evident, that if the line of direction of the upward pressure—that is, a vertical line through B—meets the axis above the centre of gravity, as at M, the tendency of the two forces is to bring the axis into its original position, and in that case the equilibrium of the body is stable. But if BM meet the axis below G, the tendency is to bring the axis farther and farther from the vertical, until the body get into some new position of equilibrium. There is still another case; the line of support or buoyancy may meet the axis in G, and then the two forces counteract one another, and the body remains in any position in which it is put; this is called *indifferent* equilibrium. In a floating cylinder of wood, for instance, B is always right under G, in whatever way the cylinder is turned.

When the angles through which a floating body is made to roll are small, the point M is nearly constant. It is called the *metacentre;* and its position may be calculated for a body of given weight and dimensions. In the construction and lading of ships, it is an object to have the centre of gravity as low as possible, in order that it may be always below the metacentre. With this view, heavy materials, in the shape of ballast, are placed in the bottom, and the heaviest portions of the cargo are stowed low in the hold.

SPECIFIC GRAVITIES OF BODIES.

If a lump of sulphur is weighed in air, and found to be two ounces, when weighed in water it will be found to weigh only one ounce. Now, as we know that the weight which a body loses in water is exactly the weight of an equal bulk of water, we infer that a body of water equal in size to the lump of sulphur weighs an ounce. Bulk for bulk, then, sulphur is twice as heavy as water, or their weights are as 2 to 1. *The specific gravity of a body, then, is its weight compared with that of water.* In tables of specific gravities, that of water is generally expressed by 1, but sometimes also by 1000. Thus, with water as 1, the specific gravity of sulphur is 2; of iron, 7; with water as 1000, these substances would be 2000 and 7000 respectively (see No. 13). The process of determining specific gravity varies with the nature of the substance; it requires delicate apparatus and delicate handling.

Instruments for readily indicating the specific gravities of liquids are called *hydrometers*, from two Greek words signifying *water* and *measure.* The name *areometer* (Gr. measurer of *rarity*) is also applied. Hydrometers are of various kinds; but the general principle on which they act will be understood from the accompanying figure. *b* is a glass ball, with a smaller ball, *c*, below it, containing shot, in order to make the instrument float upright; the fine stem, *ed*, being uniform and graduated. Suppose the hydrometer first immersed in water, it sinks until the water displaced equals the weight of the whole instrument; if placed next in a liquid rarer than water, it must sink farther, so as to displace more of the liquid, before it is in equilibrium. By knowing what part of the volume of the whole instrument each division of the stem is, we get the comparative volumes of water and of the liquid that sustain the same weight; and then the specific gravities are inversely as the volumes. It is evident that the thinner the stem, the more delicate will the instrument be. Hydrometers are made to indicate a difference in specific gravity of 1 part in 40,000.

Fig. 21.

The heaviest substance known is platinum, whose specific gravity (when rolled) is **22**; the lightest is hydrogen gas. The standard of comparison for gases is atmospheric air, which, at 60°, is 800 times lighter than water. Its specific gravity is taken at 1000. Hydrogen is fourteen times lighter than air, while carbonic acid and chlorine are more than twice as heavy as air. The vapour of iodine is eight times the weight of atmospheric air.

Spirits, such as brandy, whisky, gin, &c. consist of alcohol and water in varying proportions; and as the excise-duty is charged according to the amount of the alcohol, it is important to be able to tell at once what proportion or percentage of alcohol is present in any spirit. Alcohol, or spirit of wine, without any water—absolute alcohol, as

it is called—has a specific gravity of ·796, water being 1. The stronger any spirit is, then—that is, the less the proportion of water it contains—the lighter it is; and in this way the hydrometer becomes the means of measuring the strength of spirits. The hydrometer used by the officers of excise is of the kind known as Sikes's Hydrometer. What is called 'proof-spirit' consists of equal weights of alcohol and water, and has a specific gravity of ·92. When placed in this liquor, the exciseman's hydrometer sinks to a point on the scale marked *proof*. In a stronger, and, therefore, lighter spirit, it will sink farther, and the spirit will be so many degrees 'above proof.' The contrary takes place with a weaker spirit. The degrees are so contrived that a spirit that is, we shall say, 11° overproof, would require 11 measures of water added to every 100 measures of the spirit, in order to reduce it to proof.

As heat expands liquids, rendering them specifically lighter, great attention must be paid to the temperature of those experimented upon, as otherwise wrong results will be obtained. The standard temperature is 60°, and observations taken at any other temperature have to be reduced to the standard by certain rules.

HYDRODYNAMICS.

Hydrodynamics treats of the laws of the motion of liquids; the flow of water from orifices and in pipes, canals, and rivers; its oscillations or waves; and its resistance to bodies moving through it. The term Hydraulics is sometimes applied to this part of the subject, from the Greek word *aulos*, a pipe. The application of water as a moving power forms the practical part of the subject.

Efflux.—If three apertures, A, B, C, are made at different heights in the side of a vessel (fig. 22) filled with water, the liquid will pour out with greater impetuosity from B than from A, and from C than from B. The velocity does not increase in the simple ratio of the depth. The exact law of dependence is known as the theorem of Torricelli; the demonstration is too abstruse for introduction here, but the law itself is as follows:

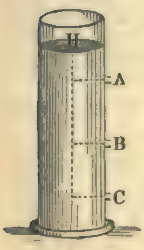


Fig. 22.

'*Particles of fluid, on issuing from an aperture, possess the same degree of velocity as if they had fallen freely, in vacuo, from a height equal to the distance of the surface of the fluid above the centre of the aperture.*' The jet from B, for instance, has the same velocity as if the particles composing it had fallen in vacuo from H to B. Now, the velocity acquired by a body in falling is as the time of the fall; but the space fallen through being as the *square* of the time, it follows that the velocity acquired is as the square root of the space fallen through. In the first second, a body falls sixteen feet, and acquires a velocity of thirty-two feet. If C, then, is sixteen feet below H, a jet from C flows at the rate of thirty-two feet; and if A is at a depth of four feet, or one-fourth that of C, the velocity of the jet at A will be half the velocity of that at C, or sixteen feet. In general, to find the velocity for any given height, multiply the height by 2×32, and extract the square root of the product.

The area of the orifice and the velocity of the flow being known, it is easy to calculate the quantity of water discharged in a given time. Thus, suppose the area to be one square inch, and the velocity twenty feet a second, it is evident that there issues in a second a cylinder or a prism of water one square inch in section and twenty feet long, the content of which is $1 \times 240 = 240$ cubic inches. This is true only on the supposition that the water in the vessel or reservoir is kept constantly at the same height.

The 'Contraction of the Vein.'—When, by means of the area of the opening and the velocity thus determined, we calculate the number of cubic feet or of gallons that *ought* to flow out in a given time, and then measure the quantity that actually does flow, we find that the actual flow falls short of the theoretical by at least a third. In fact, it is only the central part of the jet, which approaches the opening directly, that has the velocity above stated. The outer particles approach from all sides with less velocity; they jostle one another, as it were, and thus the flow is retarded. In consequence of this want of uniformity in velocity and direction among the component layers of the jet, as they enter the orifice, there takes place what is called a 'contraction of the vein' (*vena contracta*); that is, the jet, after leaving the orifice, tapers, and becomes narrower. The greatest contraction is at a distance from the orifice equal to half its diameter; and there the section of the stream is about two-thirds the area of the opening. It is, in fact, the section of the contracted vein that is to be taken as the real area of the orifice, in calculating by the theory the quantity of water discharged.

Adjutages.—It has as yet been supposed that the issue is by means of a simple opening or hole in the side or bottom of the vessel; but if the flow takes place through a short tube, the rate of discharge is remarkably affected. Through a simple opening, in a thin plate, the actual discharge is only about 64 per cent. of the theoretical; through a cylindrical conducting-tube, or *adjutage*, as it is called, of like diameter, and whose length is four times its diameter, the discharge is 84 per cent. The effect is still greater if the discharge-tube is made conical both ways, first contracting like the contracted vein, and then widening. The effect of a conducting-tube in increasing the discharge is accounted for by the adhesion of the water to its sides, which widens out the column to a greater area than it would naturally have. It has thus a tendency to form a vacuum in the tube, which acts like suction on the water in the reservoir, and increases the quantity discharged.

Pipes.—When a conduit-pipe is of any considerable length, the water issues from it at a velocity less than that due to the head of water in the reservoir, owing to the resistance of friction. With a pipe, for instance, of one and a third inch in diameter, and thirty feet long, the discharge is only one half what it would be from a simple orifice of the same diameter. The rate of reduction depends upon the diameter of the tube, its length, the bendings it undergoes, &c. The resistance increases greatly with the narrowness of the pipes.

Rivers.—The natural tendency in the water

of a river to descend at a certain speed is checked by friction, by bends in the course of the stream, and by projections on the banks and bottom. It also flows at a slower rate of speed at and near the bottom than at the surface, and also slower at the sides than in the middle. The place at which the velocity is greatest is called the *line of current;* it is generally at the deepest part of the channel. The surface of a river is not quite level; it is slightly convex, the highest part of the convexity being at the line of current. This arises from the fact, that flowing water does not press so much laterally as if it were at rest; the more slowly flowing side particles thus press in upon the central portions that are flowing fast, and heap them up until there is equilibrium of lateral pressure.

To get the mean velocity of a river or other stream, find first the surface velocity in the line of current by observing the rate in feet per minute at which a floating body is carried down. As an approximation to the truth, the mean velocity may be taken at four-fifths of the greatest surface velocity; and if this is multiplied by the area in feet of the cross-section of the stream, the product is the discharge in cubic feet per minute.

Resistance of Water to Bodies moving through it.—This is greatly affected by the shape of the body, which ought to have all its surfaces oblique to the direction of the motion. When a cylinder terminates in front in a hemisphere, the resistance is only one-half what it is when the cylinder terminates in a plane surface at right angles to the axis; and if, instead of a hemisphere, the termination is an equilateral cone, the resistance is only one-fourth. If a globe is cut in halves, and a cylinder, whose length and the diameter of whose base are each equal to the diameter of the globe, is fixed between them, this cylinder with hemispherical ends experiences less resistance than the globe alone, the diminution being about one-fifth of the resistance of the globe. Ship-builders have become, in recent times, more alive than formerly to the importance of length and of sharp angles both at bows and stern, in order that vessels may sail well. The best form in all respects for ships is still a disputed point, though it seems to be agreed that swift-swimming fish present the nearest approach to the true model

The resistance offered to a body moving in water increases in a higher ratio than the simple one of the velocity. One part of the resistance arises from the momentum that the body has to give to the water it displaces. Moving at a certain rate, it displaces a certain quantity; moving at twice that rate, it displaces twice the quantity in the same time. But not only does it displace twice the number of particles of water; it also has to displace them with twice the velocity; the pressure of the resistance is thus not merely doubled, but quadrupled or squared. Similarly, when the velocity is tripled, the resistance arising from the simple displacement of water becomes nine times as great.

Another part of the resistance of liquids to bodies moving in them is owing to the cohesion of the particles, which have not to be thrown aside merely as separate grains, but to be torn asunder. In addition to this, when the velocity is considerable, the water becomes heaped up in front, and depressed at the other end, from not having time to close in behind, thus causing an excess of hydrostatic pressure against the direction of the motion. Owing to the combination of these causes, the real law of the increase of resistance is difficult to investigate, and the results of experiments are not a little discordant.

The law, however, established with regard to that part of the resistance arising from the displacement of the water, has an important practical application. We have seen that when the speed of a vessel is doubled, the pressure against her bows must be at least four times as great as before. Now, this fourfold pressure has to be overcome over twice the space in the same time; and this amounts to doing eight times the amount of work in one hour or in one minute that was done before, implying, of course, an eightfold working or impelling power. We thus arrive at the important conclusion, that *the impelling power required for a vessel increases as the cube of the velocity.* If an engine of twenty horse-power is sufficient to impel a steamer six miles an hour, then, to impel the same vessel twelve miles, or at twice the velocity, would require $2^3 \times 20$, or $8 \times 20 = 160$ horse-power. It thus appears that to do twelve miles in one hour requires eight times as much expenditure of coal as to do six miles in one hour; or it may be put thus: to do six miles in half an hour costs four times as much coal as to do the same distance in a whole hour.

WATER-POWER.

Water is used as a moving power, either by taking advantage of the impulse of its velocity acquired in falling or descending, or by applying its mere weight to bear down one side of a wheel. The impulse of water is used when the fall of the water is low, and is applied to an *undershot wheel,* that is, to a wheel with float-boards dipping into the stream, which sweeps under the wheel. It is evident that an undershot wheel can never receive but a fraction of the effect due to the head of water, for the water leaves the float-boards retaining at least half its velocity.

The more economical mode is to make the

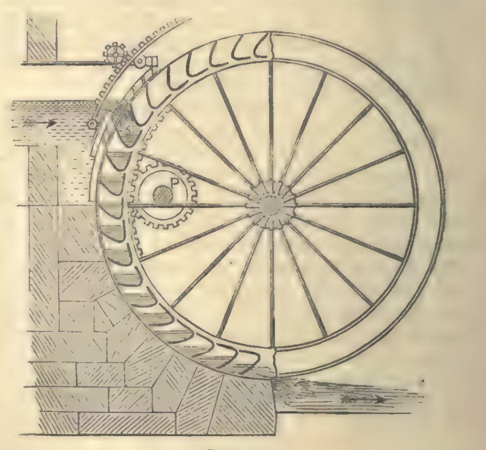


Fig. 23.

water act by its gravity, and this is done wherever

the height of fall is sufficient to allow the water to be let on above the centre of the wheel. When the channel or trough is carried over the top, the wheel is called an *overshot* wheel. This arrangement is now seldom followed. It is found preferable to make the diameter of the wheel a foot or two greater than the fall, and to deliver the water a little below the summit, as at the upper channel in fig. 23. The water may enter the bucket with greater impulse by the former arrangement, but the dash makes the bucket overflow before it is full, which more than counterbalances the advantage. When sufficient fall is not available, the water is sometimes laid on as low as the level of the axis. The term *breast*-wheel is generally applied where the water is delivered anywhere above the level of the axis without being carried over.

The absolute working-power possessed by water descending from a height depends upon the quantity and the height of the fall. If the descent is twelve feet, one pound of water is urged over twelve feet by a pressure of a pound, which makes twelve units of work, and is equivalent to the work of lifting one pound to the height of twelve feet. Therefore, the absolute work inherent in a ton of water having a descent of twenty feet, is $2240 \times 20 = 44{,}800$ units. If the stream deliver ten tons per minute, $44{,}800 \times 10 = 448{,}000$ is its work per minute; and as a rate of 33,000 units of work in a minute is what is meant by a horse-power, the power of such a stream is equal to $\frac{448{,}000}{33{,}000} = 13\frac{1}{2}$ horse-power.

But water acts fully on a bucket-wheel only from the point where the bucket is filled to the point where it begins to flow out, or for about two-thirds of the fall. Owing to this and other causes of loss, the proportion of the absolute power of the fall rendered available seldom exceeds from 55 to 65 per cent. It is advantageous, with a view to economising the power, to give a small velocity to the circumference of the wheel, not exceeding three or four feet per second.

There are a great many kinds of horizontal water-wheels. In the class known as *turbines* (Ital. *turbino*, a whirlwind), the water is made to escape horizontally from a column under pressure, inside the wheel; and, receiving a spiral direction from curved blades, strikes on the oblique palettes of the wheel, and makes it revolve. There is another class called *reaction wheels*, the principle of which is seen in the machines known as Barker's or Segner's mills. A drawing of a Barker's mill, in its simplest or typical form, is annexed (fig. 24). A is a wide metal pipe resting at its lower end by the spindle T, on a metal block B, and kept in a vertical position by the spindle S, at its upper end, which passes through the frame of the machine, so that it can easily revolve round its axis. Near its lower end, two smaller pipes or arms, C, C, are inserted, which project horizontally from it; and these have, near their outer extremities, holes cut in them, opening towards opposite sides. The water is supplied by the pipe P. The reaction caused by the water gushing from the arms, forces them backwards, and gives to the whole machine a rotatory motion. The action is similar to the recoil of a musket. More closely analysed, it may be thus explained. When an opening is made in a vessel containing water, as at C in fig. 24, the pressure is less on that side of the vessel than on the other, and if it were standing on a piece of wood floating on water, it would move in a direction opposite to the jet.

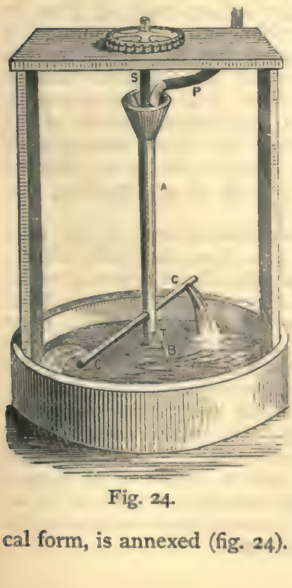


Fig. 24.

Water-column Machines.—We shall understand the nature of those machines, if we conceive that in a steam-engine, instead of steam, water, under the pressure of a high column, were admitted alternately above and below the piston.

The Hydraulic-ram is a simple and conveniently applied mechanism, by which the momentum or weight of falling water can be made available for raising a portion of itself to a considerable height. In the annexed figure (fig. 25), which represents a section of Montgolfier's hydraulic-ram, R is the reservoir from which the water falls; RS, the height of the fall; and ST, the horizontal tube which conducts the water to the engine, ABHTC. E and D are two valves, the former of which closes its cavity by ascending, the latter by descending; and FG is a pipe reaching within a very little of the bottom CB. The valves are such that the water at its normal pressure cannot support their weight; the valve E is prevented from falling below a certain point by a knob above *mn*. When the water is allowed to descend from the reservoir, after filling the tube BHS, it rushes out at the aperture *mn*, till its velocity in descending RST becomes so great as to force up the valve E, and close the means of escape. The water being thus suddenly checked, and unable to find a passage at *mn*, will produce a great action on every part of the containing vessels, and by its impact raise the valve D. A portion of water being admitted into the vessel ABC, the impulse of the column of fluid is expended, the valves D and E fall; the opening at D being thus closed, and that at *mn* opened. The water now rushes out at *mn* as before, till its motion is again stopped by its carrying up the valve E, when the operation is repeated, the fluid impulse opening the valve at D, through which a portion of the water passes into ABC. The valves at E and D thus alternately closing and opening, and water at every opening of D making its way

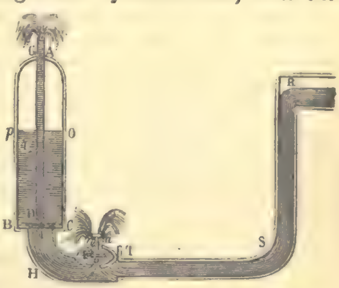


Fig. 25.

into ABC, the air therein is condensed, for it has no communication with the atmosphere after the water is higher than the bottom of the pipe FG. This condensed air, then, exercises great force on the surface, *op*, of the water, and raises it in the tube, FG, to a height proportioned to the elasticity of the imprisoned air.

The principles of the hydraulic-ram are susceptible of a very extensive application. In well-constructed rams, the mechanical effect obtained should be from 65 to 75 per cent. of the force supplied. For raising comparatively small quantities of water, such as for single houses, farmyards, &c. the ram is the best mechanism yet introduced. But the concussion, and consequent deterioration of the valves, places a limit to the use of the mechanism when applied to raise large quantities.

PNEUMATICS.

Pneumatics, from the Greek word *pneuma*, 'breath,' or 'air,' is a general term for the science of aëriform fluids, embracing both Aërostatics and Aërodynamics. What follows relates chiefly to the weight, pressure, and elasticity of gases; in other words, to the statical part of the subject. The most interesting motions of air fall under METEOROLOGY.

Modern science has made us acquainted with a number of distinct *airs*, besides common air; these are now usually called *gases*, and the name *air* is confined to the fluid composing our atmosphere. Aëriform fluids differ from one another in weight as well as liquids do; the other properties treated of in pneumatics are common to them all. Whatever, therefore, is established regarding air, is to be understood as applying to gases in general.

WEIGHT OF AIR.

The idea of air as a material fluid possessing weight and exerting pressure on everything immersed in it, is modern. The ancients thought of it as essentially *light*, or without weight, and as wanting generally the characteristics of matter. Yet it really possesses all the properties of matter, as surely as water does. A portion of it may be much compressed, indeed, but cannot be squeezed to nothing; it still occupies space, and is therefore *impenetrable* (see MATTER AND MOTION). It also resists sensibly a flat body, such as a fan moving through it; and when itself in motion, as in a strong wind, it is felt to have a powerful momentum or moving force.

With regard to the *weight* of air, nothing in the history of science is more remarkable than that men should have lived so long subject to the great pressure which this weight occasions, without discovering it. The fact is, that air acts so little on the senses, that it does not make us aware directly of its existence. The effects produced by its weight were therefore attributed to other causes. The facts, for instance, that go by the name of *suction*, are all owing to the pressure of the atmosphere. But when water was seen to rush up a pipe from which the air was withdrawn, it was explained by saying that 'nature abhors a vacuum'—that is, an empty space. This explanation continued to satisfy philosophers till the middle of the seventeenth century. Some mechanicians near Florence, having to construct a pump of unusual length, found, to their surprise, that the water refused to rise higher than thirty-four feet. This led to the conjecture, that the weight of the atmosphere was the cause of water rising in the pump; and Torricelli, the pupil of Galileo, confirmed the conjecture by a happy experiment.

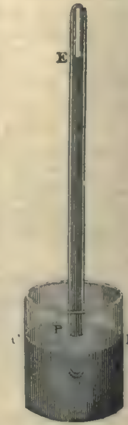


Fig. 26.

Mercury weighs nearly 14 times as much as water. If, now, he argued, the atmospheric air can support a column of 34 feet of water, it must also be able to sustain a column of mercury of about 1-14th that height. The experiment is easily made. A glass tube of upwards of 30 inches in length, and closed at one end, is filled with mercury; and the finger being firmly pressed on the open upper end, the tube is inverted, and the end closed by the finger is plunged into a vessel containing mercury, CD. The finger being now withdrawn, the liquid in the tube descends, however long the tube may be, till it stands at the height of about 30 inches above the level of that in the vessel.

All doubt on the subject was shortly after put an end to by the celebrated Pascal, who caused the Torricellian tube, as it was called, to be carried up the Puy-de-Dôme, a mountain in France. By ascending a mountain, a part of the atmosphere is left below; if it is the pressure of the superincumbent atmosphere, then, that sustains the column, the mercury must sink farther and farther as the elevation is greater. Such was found to be the case, and the question was set at rest for ever.

That air is ponderable, or has weight, can be put to direct proof. By means of an air-pump, to be afterwards described, vessels of a certain construction can be emptied of air, which, in ordinary circumstances, fills every space not occupied by other matter. When a hollow globe of glass or of copper, holding a cubic foot, is thus emptied of air, and weighed, on admitting the air again, it is found to be about an ounce and a quarter heavier than before. As a cubic foot of water weighs 1000 ounces, water, at the ordinary height of the barometer, is thus about 800 times heavier than air. It is sufficiently accurate for most purposes to consider a cubic foot of air as weighing one ounce.

Weight of the whole Atmosphere.—If the tube (fig. 26) is an inch in area, the column of mercury, PE, 30 inches high, weighs about fifteen pounds. Now, as this weight is sustained by the pressure of the atmosphere, that pressure must be equal to a weight of fifteen pounds on every square inch of surface. By multiplying the number of inches on the surface of the globe by fifteen, the product is the weight of the whole atmosphere in pounds. It is the same as the weight of an ocean of mercury spread over the whole globe to the uniform height of 30 inches, or of one of water 34 feet deep, or of one of oil 37 feet deep. It has been calculated to amount to 77,670,000,000,000,000 tons.

THE BAROMETER.

In the Torricellian tube above described, we have the well-known instrument called a *barometer* (from two Greek words signifying 'weight' and 'measure'). The weight of the atmosphere is liable to fluctuations, and these are marked by the rising and sinking of the top of the column at E. The height of the column varies, at the level of the sea, from 28 to 31 inches, the average height being 29·7. A scale is attached to the tube to mark the rise and fall. It is important to observe, that the height of the column is counted from the level of the mercury in the open vessel, and that this level is not steady. If the column sink, for instance, part of the mercury in the tube descends into the basin, and raises the level of the surface. When the basin is comparatively wide, the rise is insignificant, and is seldom attended to; but where great accuracy is required, either the scale is so constructed as to allow for the alteration of level, or the bottom of the basin is made flexible, and can be raised up and down by a screw, so as to bring the surface of the mercury always to the same point on the outside of the tube.

Barometers are of various constructions, according to the uses they are intended for. The common *weather-glass* consists of a glass tube, upwards of thirty inches in length, closed at one end A, and bent upwards at the open end C, as represented in fig. 27. The height of the column sustained is here to be counted from E down to a point on the tube on a level with F, the surface of the fluid in the open end. On the surface of F there floats a small ball, from which a thread is passed over a pulley G, and kept stretched by a lighter ball W. When the column at E sinks, the surface at F rises, and carries up the float, and the friction of the string turns the pulley, and with it the index H, whose motions are marked by a graduated circle. Such instruments are not capable of any great accuracy in ascertaining the actual height of the column; they indicate, however, generally whether it is high or low, and whether it is rising or falling, and these are the chief points in prognosticating the weather. (See METEOROLOGY.)

Fig. 27.

ELASTICITY OF GASES.

The laws which regulate the pressure of gases are essentially the same as those already established with regard to liquids. The fundamental fact of *transmitting pressure equally in all directions*, is as true of the one class of substances as of the other. But the effects in the case of gases are much modified by their peculiar property of *elasticity*, which requires careful consideration. The elasticity of gases involves two things—compressibility and expansibility, and in the case of common air, both properties are without any known limit.

Air unlimitedly Compressible.—The compressibility of air follows a remarkable law. Let *ab* (fig. 28) be a cylinder 12 inches long, closed at *b*, and open at *a*, having an air-tight piston, *d*, moved up and down by the rod *c*. Before the piston is inserted, the air in the cylinder sustains the usual pressure of the atmosphere, which is resting upon it at the open end *a*; and if the area is an inch, the amount of the pressure is 15 pounds. When the piston is placed on the open end, and about to enter, the direct action of the outer air is cut off, but it continues to act on the upper side of the piston, so that the column inside still sustains 15 pounds. Let the rod be then loaded with weights till the piston descend through half the cylinder, so as to squeeze the confined air into half its original bulk; it will be found that 15 pounds have been laid on. The piston is now forced down with a weight of 15 pounds, in addition to the weight of the outer atmosphere; the pressure on the confined air is thus exactly *doubled*, and the effect is to compress it into *half* the space.

If the weight is *tripled* by adding 15 pounds more, the piston descends two inches farther to *e*, and the air is reduced to *one-third* of its original bulk. An additional 15 pounds, making in all *four* atmospheres, sinks it to *f*, *one-fourth* from the bottom; and *twelve* atmospheres leave the air confined between *b* and *g*, *one-twelfth* of the whole space. This regular progression holds good, without variation, for atmospheric air up to at least twenty-seven atmospheres.

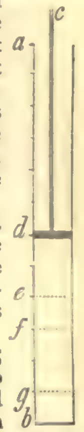


Fig. 28.

It follows from this that *the elastic force or tension of compressed air—that is, the force with which it seeks to expand—is exactly equal to the compressing force, and inversely, as the space it occupies.* At *f*, the air in the cylinder reacts upon the piston with a force of four atmospheres; at *d*, where it occupies twice the space, it presses up the piston with a force of only two atmospheres; at *a*, the under side of the piston is pressed with a force of one atmosphere, so as exactly to balance the weight of the external air. The law now explained was discovered independently by the two philosophers Boyle and Mariotte, and is known as *Boyle's Law*, or *Mariotte's Law.*

Air expansible without Limit.—The spring of air is not like that of a compressed feather or of a piece of india-rubber, which loses its tension as soon as it regains its original condition; air cannot be said to have any original volume, for it is always striving to occupy a larger space. Suppose an opening at the bottom of the cylinder (fig. 28), and let the piston be at *f*; its upper and under sides sustain each 15 pounds, for the external atmosphere is admitted to both; and air, like water, presses equally in all directions, up as well as down. If the opening is now closed by a plug or a stop-cock, cutting off the external air from acting on the under side, the piston does not move, because the confined air presses on the under side, not by its weight, but by its expansive force, as much as the external air on the upper.

Let the piston be next drawn upwards, and the air not only follows it, but continues to press upon the under side of it, though with a diminishing force. When the piston has risen to *d*, the air occupies twice its original bulk, and its tension or pressure against the under side of the piston is reduced to one-half, or 7½ pounds; and if its

volume is again doubled by drawing the piston to *a*, its elastic force falls to one-fourth, or 3¾ pounds. Thus the law of Mariotte holds for rarefied air as well as for condensed air.

HEIGHT OF THE ATMOSPHERE.

Air at the level of the sea being, in round numbers, 11,000 times lighter than mercury, it would require a column of air of that density to be 11,000 times 30 inches, or nearly five miles, high, to balance the mercury in the barometer; and this would actually be the height of our atmosphere if air were like water, of uniform density throughout its whole depth. But we could conclude even without trial, that the air must become rarer and rarer as we ascend, there being at every stage a diminished mass pressing it down; and experience verifies the conclusion. At the height of about three miles, the barometer shews that one half the mass of the air is below, so that the density at that point is reduced to one half. While, therefore, an ascent of 500 feet above sea-level makes the barometer fall half an inch, an ascent of 500 feet above three miles produces only half that fall. That the air does not extend indefinitely into the planetary spaces, we infer from the consideration that its elastic force diminishes as it becomes rarer, and is further weakened by the increasing cold of the upper regions. There must thus be a limit at which the tendency of a molecule to recede from the rest is balanced by the action of gravity drawing it towards the earth. From various appearances, it is inferred that the atmosphere extends to the height of at least 100 miles, if not much farther.

The regular decrease in density which would follow from Boyle's law, is interfered with by the decrease of temperature, which is subject to much irregularity and uncertainty. Were it not for this, the barometer would furnish a ready means of measuring heights. As it is, the rule is too complex for explanation here.

THE AIR-PUMP.

The air-pump, by which air is removed from vessels, acts by means of the expansibility of the fluid. There are various forms of the instrument; fig. 29 represents one of the simplest. R is the glass-receiver, or vessel to be exhausted, standing on a smooth plate P, and fitting so exactly, that no air can penetrate between them. From an opening in the middle of the plate, a tube passes down to the sole of the frame, and then along to the end, where it opens into the bottoms of the two pumps or syringes, as is seen in fig. 30, which represents the syringes A, A′, in section. The piston-rods, R, R′, are alternately raised and depressed by turning the pinion *o* backwards and forwards by the handle H (which, for facility in working, is often made double, as represented in fig. 29). As the piston, P, descends, the valve, V, is closed, and that in the piston opens and allows the inclosed air to escape. When the piston has reached the bottom, and begins to ascend, the valve in P closes, and a vacuum would be formed, were it not that the air in the receiver, R, and the connecting tube being relieved of the pressure of the outward atmosphere, expands, and opening the valve at V, fills the barrel below the piston. Thus, when the piston reaches the top of the barrel, the air that was at the outset confined in the receiver and tube, now fills a larger space, and is therefore so much rarer. The action of the other syringe is exactly the same; and the two do not interfere with each other, as the valve at V′ is always shut when that at V is open. Some air-pumps have only one syringe; and the chief use of two is for rapidity of exhaustion. Although every stroke of each piston removes a barrelful of the inclosed air, it must be remembered that that air is continually becoming rarer, so that the absolute quantity removed becomes less and less for every stroke. The whole of the air could never thus be removed, even in theory; and in practice, a limit is put to the degree of rarefaction by the elasticity of the remaining air becoming too feeble to raise the valves. The syphon-gauge at G shews to the eye how far the exhaustion has proceeded. It is constructed on the principle of the bent-tube barometer, fig. 27. When the process of rarefaction has reached a certain point, the mercury begins to descend in the closed leg of the tube; and if the exhaustion could be made complete, the two surfaces would be on the same level.

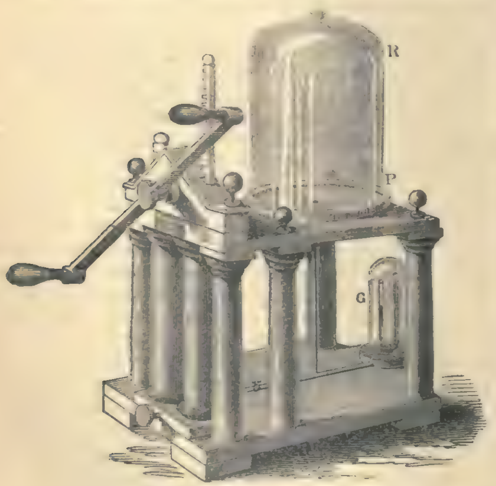


Fig. 29.

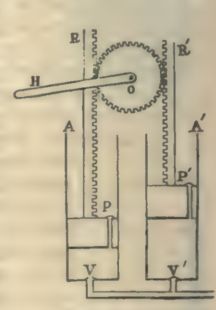


Fig. 30.

The *condensing pump*, or syringe, is the counterpart of the exhausting air-pump. By means of it, a receiver can be charged with an amount of air that would fill it many times at the ordinary density, and experiments can thus be tried on bodies inclosed in the receiver, under the pressure of many atmospheres.

A condensing syringe is used for charging the chamber of air-guns, which consists of a strong hollow copper ball. The valve of this chamber being then suddenly opened by the trigger, a portion of the highly compressed air is allowed to escape into the barrel behind the ball, which it propels with great velocity.

WATER-PUMPS.

The effect of atmospheric pressure on water affords a convenient method of raising it above its ordinary level; this is effected by pumps, which may be termed both hydraulic and pneumatic machines. Fig. 31 represents the outline of a common suction-pump. It consists of a cylinder, furnished with a piston, A, made to fit air-tight. In this piston there is a valve opening upwards, but here indicated as closed. At the bottom of the cylinder or barrel there is another valve, B, opening upwards; and from the bottom proceeds a feeding-pipe, and dips more or less into the water. When the piston is raised, the air under it is rarefied more and more at each stroke, and the pressure of the air upon the surface of the water on the outside of the pipe causes the water to rise inside where the pressure is lessened. The valve B is at the same time opened upwards, and the water, after several strokes, rushes in above it. When the upward stroke of the piston is complete, it is again depressed—the water passes through the valve in the piston, and on the next stroke it is discharged at the spout.

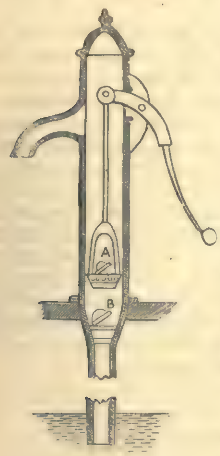


Fig. 31.

In this form of pump, the greatest height to which the water can be raised, counting from the level of the water in the well to the bottom valve, B, is, in theory, 34 feet. In practice, however, owing to the imperfect vacuum, the limit is usually from 20 to 28 feet. But with the *forcing-pump*, fig. 32, there is no such limit. The mode of its action will be understood from the accompanying outline. A feeding-pipe connects the water and the barrel, as in the suction-pump; but the piston, P, is solid, or without a valve, and a pipe, called the ascension-pipe, provided with a valve opening from the barrel, enters near the bottom. When the piston is lifted, the valve, S, closes, and the water rises through the feeding-pipe and suction-valve, on the same principle as in the suction-pump. The piston being raised to the top of the barrel, and the space below it being filled with water, it is now pressed down; the valve V closes, that at S opens, and the water is forced up the pipe to the required height.

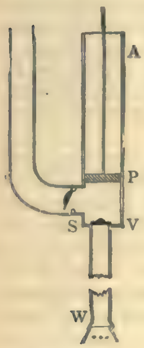


Fig. 32.

The Fire-engine.—The fire-engine is an application of the force-pump. The principle of its action, and its connection with the pumps, &c. will be easily understood by the aid of the annexed diagram (fig. 33), where *a* represents in section a piston ascending, *d* the other piston descending, *f* the pipe or hose communicating with the water-supply, *g* the hose that conveys the issuing stream to the fire, *bc* the level of the water in the air-chamber, *e* the space above filled with compressed air. The rising piston raises the water from *f* to fill its cylinder; the descending piston forces the water contained in its cylinder into the bottom of the air-chamber, and thereby compresses the air in *e*. The pistons rise and descend alternately. The compressed air reacts by its elasticity, and pressing upon the surface *bc*, forces the water through the hose *g*. In the space *e*, above *bc*, the whole of the air that formerly filled the chamber is supposed to be compressed. Assuming this to be one-third of its original bulk, its pressure will be about 45 lbs. to the square inch, and this pressure will be continuous and nearly steady, if the pumps act with sufficient force and rapidity to keep the water at that level.

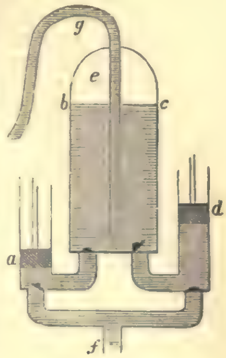


Fig. 33.

The Syphon.—The action of the syphon will be readily understood from the principles already illustrated. It is simply a bent tube, with one end inserted in a liquid, as shewn in fig. 34. To begin the action, the air is withdrawn from the tube by means of the mouth or a syringe, when the liquid enters and fills it, as in other cases of suction. When the suction is stopped, there are two forces acting on the liquid in the tube—the pressure of the atmosphere on the liquid in the vessel, forcing it in the direction from C towards B and A, and the pressure at A forcing it in the opposite direction. These two pressures are of themselves equal, and when the lengths of the columns of liquid in the two legs are equal, there is no flow; but when one column, as AB, is longer than the other, its weight destroys the balance, and produces a flow towards itself.

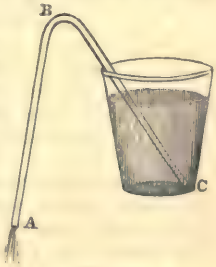


Fig. 34.

Pressure of the Atmosphere on the Human Body.—The body of a man has, on an average, a surface of about 2000 square inches. At the rate, then, of fifteen pounds to the square inch, the whole pressure which a person of an ordinary size sustains on the surface of his body is 30,000 pounds, or nearly fourteen tons. It gives a wrong notion of this pressure to speak of it as a load. It has, on the contrary, a buoyant effect, and makes a man lighter, or press less on the earth, than he would without it.

The reason why this compression is not felt, and does not in effect squeeze the body into less bulk, is, that there is an equal pressure *outwards* at all parts. In fig. 1, a force of a pound pressing in the plug *a*, is felt as an equal force pressing out the plug *b*. Now, the blood and other liquids in

the body, though contained in tubes, transmit pressure through all their ramifications, as the water in the box B does through its mass; and the direct pressure of the atmosphere on any spot of the outer surface, tending to squeeze in the sides of the tubes containing the fluids, is met by an equal pressure on the part of the fluids, tending to force them out; which outward pressure itself is caused by the atmosphere pressing on other parts of the system.

We are as little sensible, in ordinary circumstances, of this outward pressure of the fluids on the vessels of the body, as we are of the compressing force of the atmosphere. But it makes itself felt whenever the external pressure is removed from any part, as in the familiar act of sucking the finger, or more strikingly in the operation of *cupping*. A small bell-shaped glass, in which the air has been rarefied by burning a slip of paper, or by other means, is suddenly applied to a flat surface of the body. The small portion of air under the glass, as it cools, presses with diminished force on the surface of the skin; and the fluids within, released from the usual check, swell out the vessels and skin, and if a wound has been made with a lancet, the blood is forced out.

When the usual pressure of the atmosphere is much diminished over the whole body by ascending great heights, uneasy sensations are often felt, occasioned most likely by air contained in the liquids and in cavities of the solid parts of the body, seeking to expand.

A boy's sucker lifting a stone affords a good illustration of the operation of atmospheric pressure. Correctly speaking, the sucker does not lift the stone; it only lifts the weight of a column of the atmosphere from off the stone, and thus allows the remaining atmospheric pressure to push it up.

The bird-cage fountain and the ink-bottle of the same make, are other illustrations. The same cause sustains the liquid in such a vessel that sustains the column of mercury in fig. 26, and keeps it from flowing out at C—the atmospheric pressure, namely, on the surface at C, while the top at A is close, like the top of the tube in fig. 26.

Fig. 35.

The ink is introduced into a bottle of this kind by inclining it over, and pouring in gradually at C. When the ink in the tube CB sinks down by use to the level of the horizontal communication, a bubble of air gets in, and rising to the top at A, fills part of the space, and forces down a portion of ink into C.

On the principle now explained, if the lid of a tea-pot were quite close, so as to exclude the pressure of the atmosphere from the top of the liquid within, the liquid could not be poured out. It is for this reason that in drawing liquor from an opening in the lower part of a cask, there must be a vent-peg at the top to admit air.

BUOYANCY IN AĒRIFORM FLUIDS.

The fundamental law in this is exactly the same as in liquids. A body in air displaces its own bulk of the air, and is borne up with a force equal to the weight of the air so displaced. If the body's own weight is less than this, it must rise up, as a piece of cork does in water; if greater, the body only loses a portion of its weight, as a stone in water.

In weighing bodies in air, the fact that the air deprives them of part of their weight, does not interfere with the accuracy of the process so long as the substance is nearly of the same density as the weight against which it is balanced, because then both are equally affected. But where there is great difference of density, it leads to sensible error. A pound of feathers—as it is sometimes paradoxically stated—is heavier than a pound of lead—that is, it contains more matter. If a quantity of feathers occupying a cubic foot of space, were balanced in a vacuum against a piece of metal, the balance would be destroyed on taking them into the air. The feathers would lose above an ounce—the weight of a cubic foot of air—the metal would lose only a few grains.

BALLOONS.

Solid bodies cannot of themselves float in air, being all heavier than an equal bulk of it; but by inclosing air rarefied by heat, or a light gas, such as hydrogen, in a bag, it may be made to buoy up more or less solid matter along with it. Such a contrivance is a balloon. A soap-bubble blown from hot water with warm air, is the simplest form of balloon, but soon loses its buoyancy by cooling; if blown with hydrogen, it continues ascending till it bursts. A body floating in air rises till it arrives at a stratum of the atmosphere whose density is the same as its own.

A balloon is a bag made of varnished silk, and surrounded by a net-work, from which a car is suspended. Balloons were originally filled with heated air, and had a fire suspended in the opening below, to keep up the temperature. So far as lightness is concerned, hydrogen would be the best gas for the purpose; but, from its cheapness, common coal-gas is generally employed, whose density is about half that of air.

The air contained in a room fifty feet long, thirty wide, and twenty high, weighs upwards of a ton. A balloon of this capacity (30,000 cubic feet) would thus displace a ton of air, while the gas contained in it weighed only half a ton; it would therefore ascend with a force equal to the difference, or half a ton, after deducting, of course, the weight of the silk, the car, and other parts of the apparatus.

The most remarkable recent balloon ascents have been made by Mr Glaisher for the purpose of meteorological observations. On one occasion he ascended to a height of about 40,000 feet (7½ miles), the barometer standing at 7 inches. The balloon contained 90,000 cubic feet of gas, and carried a load of 600 lbs. As it is impossible to direct the horizontal motion of balloons, they are almost useless as a mode of conveyance. During the siege of Paris in 1870, a few persons made their escape in balloons from the city to the provinces, but there could, of course, be no return.

LIGHT AND SOUND.

LIGHT.

LIGHT (German, *licht;* Latin, *lux*, *lumen;* French, *lumière*).—That branch of physical science which treats of light and vision is termed Optics, from a Greek word meaning *to see.* To explain the production of light, let us first state two suppositions, which are now all but universally admitted to be true. *First*, all matter is built up of small particles, which are in a constant state of vibration. There are many ways of increasing the rapidity of these vibrations, of which it is sufficient to mention friction, chemical action, heat. When the vibrations become sufficiently rapid, the body becomes luminous. *Second*, pervading all space, and even the interstices between the component particles of matter, there is a subtle, highly elastic medium called ether, which can be agitated by the vibrations of these particles, thus forming ethereal waves. We see objects by these waves entering our eyes, and acting on the nerves of the retina. This theory has been successful in explaining all the facts of vision, and some even that at their discovery seemed opposed to it. Besides, consequences have been deduced from the theory that have been afterwards verified by experiments, so that its truth is in the highest degree probable. The only other theory at all deserving of consideration was that devised by the illustrious Newton, who supposed that luminous bodies throw off streams of particles in all directions, some of which entering the eye, produce vision. There are now so many facts that are utterly inconsistent with this hypothesis, that it has been generally abandoned; though, owing to the influence of Newton's name, it long reigned supreme. This is called the *emission* theory, as the former is called the *wave* or *undulatory* theory of light. In what follows, we shall adhere to the wave theory.

With regard to their power of exciting the sense of vision, bodies may be divided into luminous and non-luminous, or those whose vibrating particles can, and those whose vibrating particles cannot, produce those ethereal waves fitted to act on the retina. The sun, the fixed stars, a fire, the flame of a candle, a piece of glowing metal, are instances of the first class, or luminous bodies, which can be seen in the absence of other bodies; while the second class cannot be seen, except in the presence of one of the first, in a way to be presently explained.

Light proceeds from a luminous body in all directions; thus the flame of a candle is seen on whichever side of it we stand. Also each small part of a luminous surface gives out its own share of the whole light; so that, when we wish to have a luminous point, we place a screen, with a small hole in it, in front of the luminous surface. Bodies are said to be transparent when they permit light to pass through them, as a sheet of glass; and opaque, when they stop it completely, as a thick sheet of metal. No body is so transparent as to allow all the light to pass through it, for even the purest glass, if thick enough, will stop some light; and, on the other hand, if we take a thin enough sheet of any opaque body, some light will be transmitted. Gold-leaf, for example, exhibits a pale green tinge when held between a light and the eye.

In every uniform medium, such as air, water, glass, a vacuum, light is propagated in straight lines. Thus we can see through a straight tube, but not through a bent one. A shadow is a correct outline of the object which throws it, which could not be the case if light did not travel in straight lines. Any one of these lines, proceeding from a luminous point, is called a *ray* of light; and a bundle of rays is called a *pencil* of rays, which may be a parallel, diverging, or converging pencil, according as the distance between the component rays remains the same, increases, or diminishes.

Light is not transmitted instantaneously, but travels at the rate of 186,000 miles per second. This fact was first established in 1675 by a Danish astronomer, Römer, whose reasoning may be illustrated by the following diagram.

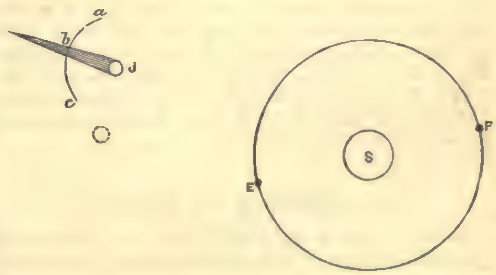


Fig. 1.

Let S represent the sun; E, F, the earth in two positions in its orbit, at considerably different distances from J, the planet Jupiter; and *abc*, a portion of the orbit of Jupiter's first satellite. At *b*, the satellite is just plunging into Jupiter's shadow, and a spectator at *e* sees it suddenly disappear. Six months afterwards, the earth is about F, while Jupiter has not materially altered his place (the small circle below J indicates his real place); and as the satellite revolves in a little over forty-two hours, the spectator at F again sees the eclipses, but they are now about a quarter of an hour later than the times calculated from those at E. Römer simply and rightly explained this fact by saying that the eclipses really happened at the calculated times, but that light took the additional time to travel the extra distance to F. By careful calculations he thus deduced the velocity of light to be 195,000 miles per second; but as the sun's distance from the earth is now known to be less

than it was supposed to be in his time, this estimate is too large.

As light advances from its source, it becomes weaker, though not in the ratio of the distance. If we take a board, *a*, a foot square, and place it at any distance from a candle, it will be found to

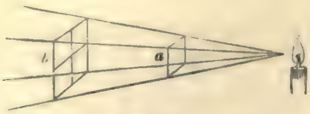


Fig. 2.

hide the light from another board, *b*, two feet square, at double the distance. Now, the latter board having four times the surface of the first, the light spread over it, when *a* is removed, must be four times weaker. Thus we say, when the distance is doubled, the intensity is one-fourth; similarly, when the distance is increased three times, the intensity is diminished nine times; and generally, in whatever ratio the distance is increased, the intensity is diminished in the square of that ratio.

This law is made use of in the construction of photometers, or instruments to measure the intensity of light. There are many varieties of the instrument, but the most convenient and extensively used is Bunsen's. A screen of white opaque paper, which can be moved backwards and forwards on a divided scale, has a round grease-spot in its centre. If a light is on the same side of the screen as the eye, the central spot appears dark on a white ground; but if the light is on the opposite side, then the spot is light on a dark ground. If, now, we have a light on each side of the screen, and if we shift the screen until the whole of it appears of one uniform tint, it is clear that the intensity of each light is as the square of its distance from the screen.

REFLECTION OF LIGHT.

When a ray of light, CD, falls on a plane and polished surface, as AB, it is bent back or reflected

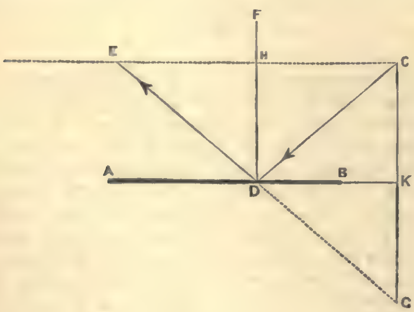


Fig. 3.

in DE, making the angle EDA equal to the angle CDB. If the surface is not plane, it is more convenient to draw the perpendicular DF, and then the angle CDF is equal to EDF, or the angle of incidence is equal to that of reflection. The truth of this law may be experimentally shewn by laying a plane looking-glass, AB, on a table, with its front all covered except a small patch at D, over which a plummet, FD, hangs. A candle-flame, C, is now placed just as high above the table as the eye of the observer is, and it will be found on trial that the only point where the flame is visible is a point, E, whose distance from the plumb-line is the same as C's.

If we draw the line ED backwards, and measure off DG equal to DC, then an eye anywhere in the line ED will see the light as if coming from G, which is therefore called the image of C. If we connect C and G by a straight line, meeting the direction of the mirror in K, it will be found that CG is perpendicular to AK, and that CK is equal to KG. Hence the following rule to find the position of the image of a luminous point formed by a plane mirror. Draw a perpendicular from the point to the mirror, and continue the line backwards its own length beyond the mirror; the extremity of the line is the image of the luminous point.

To trace the course of the pencil of rays by which any point of an object is seen after reflection. Let A be any point of the object; B, the image of A, determined as before. From B draw the diverging pencil of all the rays which can enter the eye at E, and let these rays meet the mirror in C. Join all the points of intersection of the rays at C with A; then the pencil ACE is that by which the point A is seen.

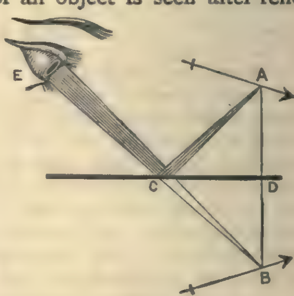


Fig. 4.

Since every point of an object has its own image just as far behind the mirror as the object is in front, the whole image must be of the same size as the object, and its position independent of the position of the eye. Suppose, again, AB to be a mirror, with an object, CD, of twice the length,

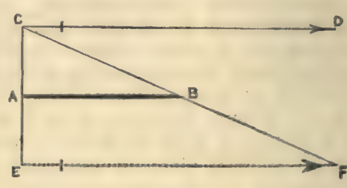


Fig. 5.

placed in front of it, and parallel to it, CA being perpendicular to AB; EF is the image; and being twice the length of AB, the direction, FC, in which an eye at C would see the point F, just passes through B. The whole of the image would therefore be seen from C. And this explains the fact, which puzzles many people, that a person can see himself full length in a mirror of just half his height.

Reflection at a Concave Spherical Surface.—The shape of such a spherical mirror resembles that of a watch-glass, silvered on the convex side, and

looked into from the other side. Let ACB be a section of such a surface through its centre, O. AB is called the aperture of the mirror; C, the

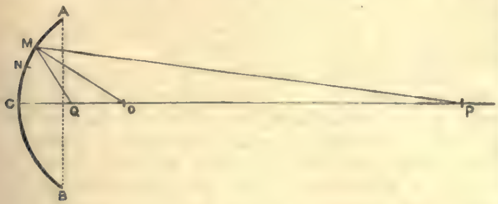


Fig. 6.

centre of the aperture; O, the centre of curvature; CO, the radius; and the line COP the axis. If PM be a ray coming from the luminous point, P, since MO is perpendicular to the surface at M, it will be reflected in MQ, making the angle OMQ equal to the angle PMO. Another ray coming from P, and striking the mirror at a different point, as N, will not be reflected exactly to Q, so that there is no exact image formed of the point P. The image is drawn out into a line, in which, however, one point is brighter than the rest: that point, namely, which is formed by rays striking near C. The farther the luminous point, P, is from the mirror, the nearer is this bright point to the middle of CO; and when P is so far off that the rays coming from it may be considered to have lost their diverging character, the bright point is exactly half-way between C and O. This point is therefore called the principal focus of the mirror, and the distance, CQ, is then called the focal length. It is clearly equal to half the radius. The indistinctness of the image, caused by all the rays not being brought accurately to one focus, is called the aberration of the mirror.

To explain the formation of images by such a mirror, let PQR be the object, AB the mirror, and O its centre. The brightest point on the image of

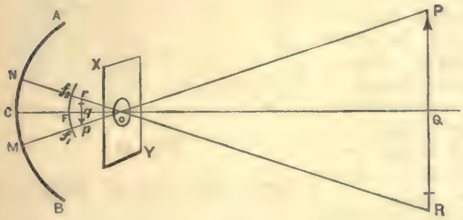


Fig. 7.

Q is *q*, rather nearer the centre, O, than F is, the middle of CO. Also for P, its principal image is in the line POM, at *p*, between O and f_1, the middle of OM. Proceeding in this way for all points of the object, PQR, we find the image, *pqr*, which we thus see is diminished and inverted.

It is to be observed also that the reflected rays actually pass through the image, which is called a real one; whereas, with a plane mirror, the reflected rays do not pass through the image, which is consequently called a virtual one. If the points P, Q, R, are in a straight line, their images, *p*, *q*, *r*, are not, so that the image of the object is curved. Again, of all the rays coming from P, it is only those striking the mirror in the immediate neighbourhood of M that are reflected to *p*, the rays falling more obliquely being reflected to different points. This produces confusion in the image, which, however, may be obviated by interposing a *diaphragm*, XY, to cut off all the indirect pencils. If we consider *pqr* as a small object, then PQR is its image, which is real, magnified and inverted, but is affected by the aberration, curvature, and confusion, as before. If the sun is the object in front of the mirror, then a small but bright image is formed at the principal focus. This explains the use of such mirrors as burning-glasses, where a parallel beam of light is made to converge to a focus. If a light is placed in the focus, then its rays are reflected in a parallel beam, and consequently such reflectors are used for lamps of coaches and light-houses. For convex spherical mirrors, the image is always virtual and diminished.

REFRACTION OF LIGHT.

It has been already mentioned that as long as rays of light are in the same medium, they travel in straight lines. If, however, the rays suddenly change their medium—for instance, if they enter water from air—their direction is suddenly changed, or they are refracted, unless they strike the bounding surface perpendicularly. In the diagram, let AB represent the ray travelling in air, and meeting the surface, CD, of the water at B. Its direction in the water is not BE, in the same line with AB, but BF, nearer the perpendicular, GBH. If we mark off equal lengths, BA, BK, in the two directions, and draw AG, LK, at right angles to GH, then

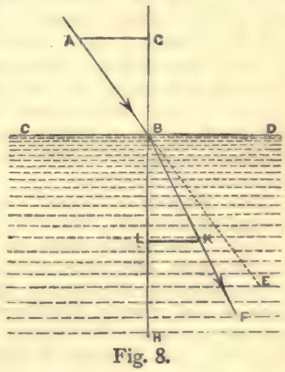


Fig. 8.

the exact law is expressed by saying that at whatever angle AB strikes the surface, the ratio of AG to KL is always the same. This constant ratio is called the index of refraction for the two media, and in the case of air and water is very nearly $\frac{4}{3}$, or LK is three-quarters of AG. If we suppose the motion of the ray reversed—that is, if it proceeds from water to air—it travels in the direction FBA, so that it is bent or refracted away from the perpendicular, GH. Thus the refraction is towards the perpendicular to the common surface if the second medium is the denser of the two, but away from it if less dense. Generally speaking, the greater the difference of density of the two media, the greater is the index of refraction. And if we take each medium with a vacuum, the index of refraction is then called the absolute refractive index. Inflammable media, if transparent, have high refractive powers; and Newton, observing the high refractive index of the diamond, conjectured that it would prove to be inflammable—a conjecture which has been subsequently verified.

The following simple experiments are well

known: Take an empty basin, and place it on a table; then lay a shilling at the bottom of the basin in such a position that the eye of the observer will just not see it. Now fill the basin with

Fig. 9.

water, and the shilling, though lying unmoved, will come completely into sight. The explanation of this phenomenon is, that the rays of light producing vision in the eye are bent on emerging from the water, and have all the effect of conveying our sight round a corner. In like manner, the refractive power of water is observable when we thrust a straight stick or instrument into it, on aiming at any object. We see that the stick seems to be bent, and fails in reaching the point which we desired it should. On this account, the aim by a person not directly over a fish must be made at a point apparently below it, otherwise the weapon will miss by flying too high. In the same way, objects at the bottom of a river appear higher up, or nearer the surface than they really are, by one-fourth of their actual, or one-third of their apparent depth. A pool which appears to be four and a half feet deep is in reality six feet deep, and fatal accidents have often happened from the ignorance of bathers on this point.

If the density of the medium changes gradually instead of suddenly, the rays are gradually bent, or curved. The rays by which we see celestial objects pass through the whole thickness of our atmosphere, which is of extreme tenuity in its highest parts, and of greatest density at the earth's surface, and consequently these rays are bent, as in the diagram. The direction in which they finally strike

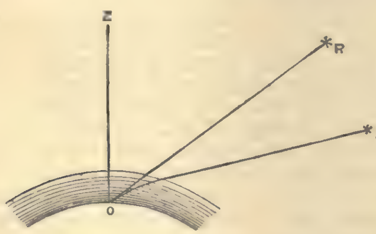


Fig. 10.

the eye of an observer at O is the line OR, and therefore a star, S, appears to be higher than it really is. If a star is right overhead, or in the zenith, as at Z, its position is not affected by refraction, as the rays by which it is seen fall at right angles on the surfaces which bound media of different density. For stars not in the zenith, the observed position must be corrected by subtracting the refraction, and this correction increases with the distance from the zenith, only much more rapidly. It is well known that when the disc of the sun or moon is seen near the horizon, it does not appear perfectly round, but seems longer from east to west than from north to south. This is because the southern limb is more raised by refraction than the northern one, while the eastern and western limbs are equally affected.

Twilight, or the gradual beginning and ending of daylight, is due partly to the refraction of the sun's rays by our atmosphere, but chiefly to their reflection in all directions by the atmospheric particles. If the atmosphere did not exist, we should have the darkness of midnight until the first streak of the sun's disc appeared above the horizon, and then suddenly this would be succeeded by broad daylight, for we learn in total eclipses of the sun that there is nearly full daylight as long as any portion of the disc is visible. But while the sun is still below the horizon, some of his rays striking the higher parts of the atmosphere are reflected downwards, and so reach the eye, and the more the nearer he is to the horizon; so that before sunrise we have all possible gradations of light, from the faintest glimmer to the full day.

It will now be evident that the directness of our vision is at all times liable to be disturbed by atmospheric conditions. So long as the atmosphere between us and the object at which we are looking is of the same density, we see as it were in a straight line to the object; but if by any cause a portion of that atmosphere is rendered more or less dense, the line of vision is not straight, or we see the object not in its true place. If the layers of air should increase in density from the earth's surface, then objects would appear lower than they really are. In the sandy plains of Africa, the intense heat of the soil at mid-day rarefies the air over it, so that the least dense layers are the lowest. Rays, then, from an elevated object, as A, are bent as in the figure, and a person at E will receive the ray as if it came from B. An inverted image of the object is thus formed, precisely as if it had been reflected from the surface of a lake. This optical illusion is called the *mirage*.

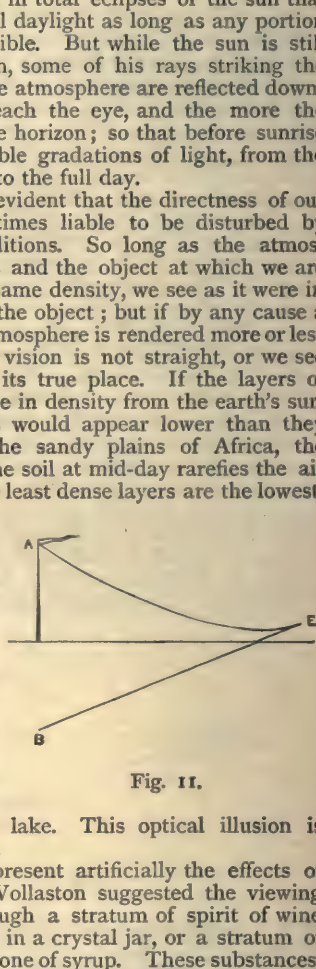


Fig. 11.

In order to represent artificially the effects of the mirage, Dr Wollaston suggested the viewing of an object through a stratum of spirit of wine lying above water in a crystal jar, or a stratum of water lying above one of syrup. These substances, by their gradual incorporation, produce a substance whose refractive power diminishes from the spirit of wine to the water, or from the syrup to the water; so that, by looking through the mixed or intermediate stratum at a word or object held behind the bottle which contains the fluids, an inverted image will be seen. The same effect, it has been shewn, may be produced by looking along the side of a red-hot poker at a word or object ten or twelve feet distant. At a distance less than three-eighths of an inch from the line of

the poker, an inverted image is seen, and within and without that, an erect image.

If the medium on which rays of light fall is bounded by two parallel faces, the rays, after passing through the plate, will be parallel to their direction before entering it, since the refraction at the one surface must be equal and opposite to that at the other. But if light falls on a refracting *prism*, it emerges in quite a different direction. Let ABC be the prism, say of glass,

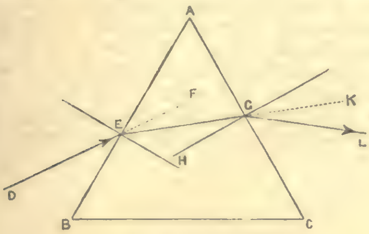


Fig. 12.

on which the ray DE falls; the direction within the prism is not EF, but EG, nearer the line EH, which is perpendicular to AB. At the second face, the ray is bent from the perpendicular GH, and takes the direction GL. By the refraction at both faces, the ray has been bent from the direction DF into GL, and the angle between these directions is called the *deviation* of the ray, which is always towards the thick part of the prism, and is proved, by a simple mathematical investigation, to be the least possible when the incident and emergent rays make equal angles with the faces of the prism.

If the refracting medium be bounded by curved faces, it is called a *lens*, and may have one or other of the following forms: A is called a double convex lens; B, convexo-plane, or plano-convex,

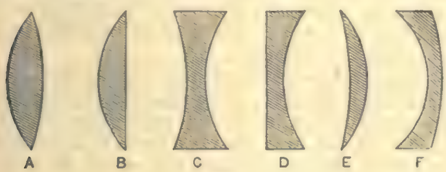


Fig. 13.

according as the light falls first on the one side or the other. C is a double concave; D, plano-concave; E, a meniscus; and F, a concavo-convex. They may be divided into two classes, according as they are thickest or thinnest in the middle; and they all, like the prism, deflect a ray of light towards the thick part. Therefore, a parallel beam of light, falling on one of these lenses, will be rendered converging or diverging, according as the lens belongs to the first or the second class. In fig. 14, the parallel rays are bent within the lens in the direction of the point A, but on emerging from the lens they are further bent, so that they converge to a nearer point, B. In the lower figure, the rays within the concave lens are bent as if they had come from C, and on leaving the lens, they seem to proceed from D. The points B and D are called the *foci* for parallel rays, or the principal foci of the lenses, and it is evident that B is a real, and D a virtual focus. The distance from the centre of the lens to the principal focus is called its focal length, and if the curvature of the two

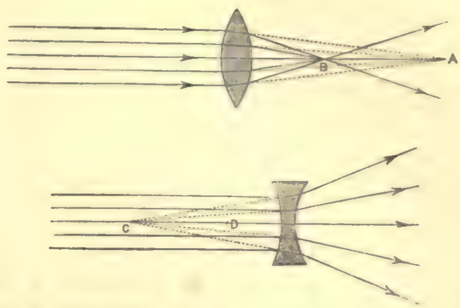


Fig. 14.

faces is the same, and both faces are spherical, this focus is at the centre of the sphere. As in reflection at a spherical surface, so likewise in refraction, rays at all distances from the axis are not brought accurately to one point, those falling on the lens near the edge being brought sooner to a focus than those near the axis. This drawing out of the focus from a point into a line is called the aberration of the lens, and might be partly remedied by covering up the parts near the edge, or those near the centre, with a stop or diaphragm. If a pencil of parallel rays falls obliquely on a lens, it is still brought very nearly to a focus, which is

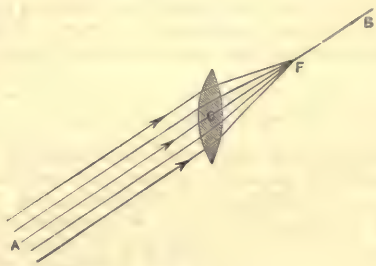


Fig. 15.

thus found. Take that ray, AB, of the oblique pencil which passes through C, the centre of the lens; the focus of the pencil lies in this line, at a distance, CF, from the centre equal to the principal focal length.

The effect of a lens thick in the middle, or convex, being to render a parallel beam convergent, it is easy to see that if a beam be already convergent, a convex lens will make it still more convergent; and if the beam be divergent, the same lens will diminish its divergency.

To understand how images are formed by lenses, let us take a double convex lens, and place an object, ABC, farther from it than F, its principal focus; all the rays coming from B, and falling on the lens, are refracted to some point, *b*, on the axis, neglecting the aberration, so that at *b* an image of the point B is formed. To find the image of A, draw a line from A through the centre of the lens, and the focus required is somewhere on this line, as at *a*, so that the rays falling on

the lens from A are all very nearly brought to a focus at this point. In this way each point of the object has its image thus formed, and

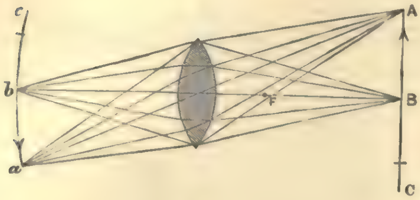


Fig. 16.

consequently an image of the object is produced, but inverted. The image is also slightly curved, as the points *a, b, c,* are not necessarily in a straight line. The relative size of the object and image will depend on the distance of the former from the lens. If this distance is twice the focal length, the size of the image is the same as that of the object; and if the distance be greater than this, the image is less than the object in the proportion of their distances from the lens. If the object ABC be the sun, the rays from it falling on the lens may be considered parallel, and therefore its image is formed in the principal focus. This gives us a method of practically finding the focal length of a lens. Receive the sun's image on a screen of ground glass, or tissue-paper, and by moving the lens or the screen backwards and forwards, with their plane always at right angles to the sun's rays, form as distinct and small a circle of light as possible: measure the distance of the lens from the screen, and this is the focal length of the lens.

THE EYE—VISION.

We can now understand the action of a lens in assisting imperfect vision. As mentioned in the article HUMAN PHYSIOLOGY, the eye, in front, consists of the *iris*, or variously coloured ring, which has the property of contracting or expanding to regulate the admission of light through the little dark spot in the centre called the *pupil*. Immediately behind the iris and pupil, there is a transparent substance resembling in shape a double convex glass, which is thence called the *crystalline lens*. The use of this lens is to collect and refract the rays of light, so that they may converge to a point beyond; in other words, cause them to fall on the back part of the eye, called the *retina*. Such are the main instruments of vision; and the sense of seeing is produced by certain nerves which convey intelligence of the image on the retina to the brain. If these nerves be injured, the image will still be pictured on the retina, but the mind will possess no power of recognising their presence.

It will be understood from these explanations that the main instrument of vision is the crystalline lens, which collects the rays, and brings them to a focus on the retina. If the lens be perfectly transparent, and of the proper convexity, the light is enabled to act with due effect on the retina, and the representation of the object looked at will be correctly pictured to the mind. But if the transparent coating of the eye be dull, or the lens be either too flat or too convex, every object will appear dim.

Two kinds of defective vision are more common than any other, and they are known by the name of *long-sightedness* and *short-sightedness*. Long-sightedness, or the power of seeing objects best at a considerable distance, is caused by too great a flatness in the crystalline lens and outer coating of the eye; and the deficiency of vision in old persons is usually from a similar cause. To remedy this defect as far as possible, artificial lenses of glass are employed. These lenses are called *spectacles*, and act in the manner we are now to describe. The following figure represents an eye in which the crystalline lens is too flat. CA is the cornea or outer covering, *b* is the crystalline lens, and *d* is the retina behind: B is the object looked at. We

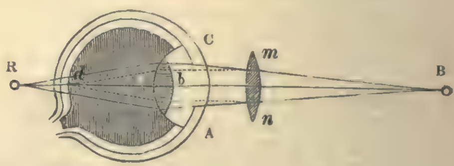


Fig. 17.

may observe, that in consequence of the flatness of the lens *b*, the rays proceeding from the object are not sufficiently refracted, but proceed to a focus as far back as R; in other words, the focus would be at R, if the retina would permit; but as the retina is in the way, the rays, from not being focalised upon it, cause imperfection in the vision. To remedy this, we interpose an artificial convex lens, or glass of a pair of spectacles, *mn*, and by its aid the rays—represented by dotted lines in the figure—are brought to a focus on the retina at *d*. Thus, by selecting spectacles of a proper focalising power in relation to the eyes, one kind of imperfect vision is very happily remedied.

Short-sightedness arises from a cause the reverse of that just alluded to, being produced by too great a degree of convexity in the crystalline lens and cornea. In this case the rays come to a focus too soon within the eye, and do not reach the retina, unless the object is brought quite close to the

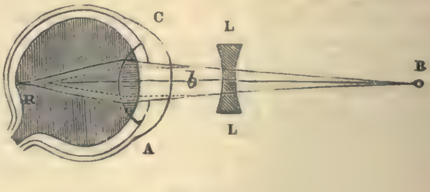


Fig. 18.

organs of vision. We here offer a representation of this condition. In consequence of the projecting globularity of the cornea, CA, and the too great refracting power of the crystalline lens, the rays from the object B fall short of the retina at R. To remedy this, we interpose a double concave lens, LL, by which the rays are rendered more

divergent before they reach the eye, and are brought to a focus, where they should be, on the retina.

We have said above, that in short-sighted persons the rays do not reach the retina unless the object is held close to the eyes. The effect produced by this is similar to that of employing concave spectacles; because the nearer we hold an object to our sight, the angle of the rays from it is the wider; the rays are more expanded before they enter the eye—that is, more divergent. Thus the extreme rays from a point to the pupil of the eye make a greater angle at *o* than those from a point of a more distant object make at *a*; that is, the rays from *o* are more divergent on entering the eye than the rays from *a*, and thus nearness of an object is equivalent to seeing it at a greater distance through a concave lens. So when the object *a* is further distant than *o*, the rays from *a* have a less divergence, which is equivalent to viewing it at a nearer distance with a convex lens. Long-sighted persons must therefore diminish the divergency of the rays falling on the crystalline lens, and this they can do either by holding the object at which they are looking at a greater distance, or by using convex spectacles. Short-sighted persons can, to some extent, remedy their defective vision by partially closing the eyes. The effect of this partial closure is to cut off those rays which would pass through the marginal parts of the lens, and which principally cause the confusion and indistinctness of their vision.

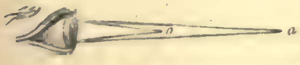


Fig. 19.

We think it unnecessary to discuss the questions why, having two eyes, we should see objects single, and why we should see objects erect, when their image on the retina is inverted, as these questions belong more to physiology and the science of mind than to optics.

DISPERSION OF LIGHT BY REFRACTION.

If the ethereal waves whose motion constitutes light were all of the same length—in other words, if light were homogeneous—refraction by prisms and lenses would be as we have described it. But when a small beam of sunlight falls on a prism, the refracted beam is not white, but is split up into a number of coloured beams. The experiment which was devised by Newton may be thus performed. In the shutter, AB, of a darkened room, a small hole, C, is made, to give entrance to a small pencil of sunlight, CD, which, if uninterrupted, would proceed in a straight line to E, and form a white spot, or image of the sun. A prism, FGH, is interposed in the path of the beam, and a screen is placed to receive the pencil emerging at K. The sun's image formed on the screen, instead of being a circular spot, is now a narrow oblong, whose width is the same as the diameter of the spot, but length many times greater. Also this stripe is coloured throughout its whole length, being red at the lowest part, R, and the colours shading imperceptibly through orange, yellow, green, blue, and indigo, to violet at V. This experiment proves that sunlight is a mixture of light of different colours and of different refrangibilities. If we make a hole in the screen at R, so as to allow only the red rays to pass through, and then place a second prism in their path, we find that they are incapable of further subdivision, and so for all the other colours. Also, if we look at the coloured stripe, or *spectrum*, as it is called, through another prism, like FGH, and placed similarly to it, all the colours are re-combined into white, and the circular image of the sun is again seen. In order that the colours of the spectrum may be pure, it is necessary, first, that the deviation should be the least possible; and secondly, that the aperture in the shutter should be small. The first condition is satisfied by turning the prism till the beam leaves the second face at the same angle as it strikes the first; or, more simply, till the spectrum occupies the lowest position on the screen possible. The necessity of the second condition will be obvious, if we consider that in a wide aperture, the highest and lowest rays will each depict its own spectrum on the screen, and that the red or orange of the lowest spectrum may overlap the orange or yellow of the highest.

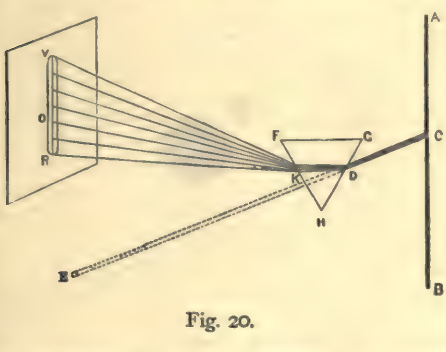


Fig. 20.

To explain the production of coloured fringes when an object is looked at through a prism or lens, let us suppose that each point of the object sends out rays of all colours. As the red rays are least refracted, there will be a red image of the object AB formed as at *ab*, and a violet one at *ef*, the other coloured images being intermediate in position. Between *e* and *b*, all the colours will be mixed in the proper proportion to form white light; and an eye at E will see the image colourless from *e* to *b*, but red predominating in *ae*, and blue in *bf*. If we vary the material of the prism, by taking, for instance, a prism of dense flint-glass, instead of one of crown-glass, we find the length of the spectrum considerably altered, and the proportions of its different parts to be no longer the same as before. Not only has flint-glass a higher dispersive power than crown-glass, but it disperses the violet end of the spectrum in a higher degree than the red end. All spectra produced by refraction are therefore said to be *irrational*. If the dispersion were always proportional to the refraction, any bending

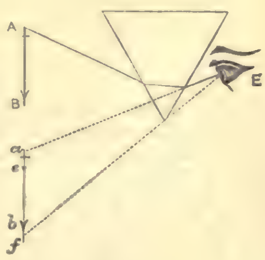


Fig. 21.

of light would always be accompanied by the production of colour, and an *achromatic* lens, or lens producing a colourless image, would be impossible. But, by opposing a glass which bends five degrees and disperses one degree to another glass which bends three degrees and disperses one, the opposing dispersions will counterbalance each other, and the refracted beam will be colourless. It is on this principle that achromatic prisms and lenses are made. The two prisms, A and B,

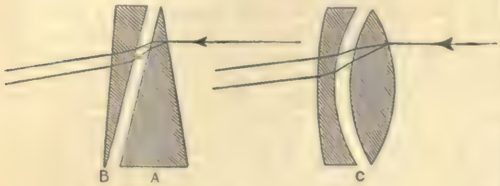


Fig. 22.

though drawn as separated from each other, are firmly fastened by a colourless cement; A is of crown-glass, and B of flint-glass, and the angle of B is so adjusted that the higher dispersive power of flint-glass is counterbalanced by the thinness of the prism, and a beam of white light passing through the combination will be deflected, but not decomposed into coloured beams. The action of the achromatic lens, C, is precisely similar; but from what has been said of the irrationality of the spectrum, no combination of prisms or lenses can be truly achromatic. The most that can be effected is to bring together any two rays of the spectrum.

When a pure spectrum of solar light is attentively examined, and especially with a magnifying eyeglass, it is seen to be crossed by many black lines; and with the same prism, these lines occupy a fixed position. Dr Wollaston, in 1802, was the first to observe and describe these lines; but Fraunhofer, an optician of Munich, rediscovered them in 1814, and published a beautiful map with the positions of many of them accurately marked. Fraunhofer discovered also that dark lines existed in the spectra of many different kinds of light, and that the lines of the spectra of the planets and of the moon were the same as those of the solar spectrum, while the spectra of the fixed stars were all different. If the source of light be a solid raised to a white heat, a spectrum is obtained without any dark lines, which is therefore continuous from end to end; if the source of light be a burning vapour, there is a remarkable change in the spectrum. Instead of being either continuous or crossed by dark lines, it consists now of one or more bright lines, which may be differently coloured. The instrument by the aid of which these phenomena may be most conveniently studied is called the spectroscope, and consists essentially of, first, an illuminated slit, from which parallel rays of light proceed: secondly, a prism or train of prisms, to separate the differently refrangible rays; and thirdly, a telescope, to view a magnified image of the spectrum produced. The following figure represents a section of the instrument in its

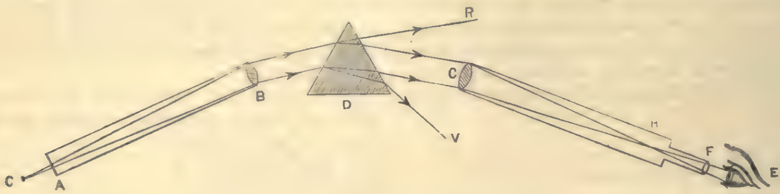


Fig. 23.

simplest form. AB is a brass tube, carrying at one end, A, a metal piece with a slit, whose width can be regulated by a fine screw, and at the other end, a convex lens, B. The source of light, C, is in the focus of the lens B, so that parallel rays fall on the prism D, by which they are scattered into the coloured beam, RGV. The telescope, FG, is movable in the plane of the figure, so as to describe part of a circle round the prism as centre, and it can therefore be directed at will to any part of the spectrum from R to V. The rays, such as G, which fall on the lens G of the telescope, are brought to a focus at H, where a distinct image of this part of the spectrum is formed. This image is in the focus of the eyeglass, F, so that an eye placed at E sees it magnified. If the part of the circle round which the telescope travels is graduated, and furnished with an index or vernier, the exact position of the telescope at any time can be read off. But a simpler plan than graduating the circle is to throw the image of an illuminated transparent scale to the focus, H, of the object-glass, G, so that the images of the scale and spectrum are seen at the same time. This is easily and ingeniously accomplished, thus: a glass circular disc, S′, has a small scale engraved in the direction of a diameter, and all the rest of the disc

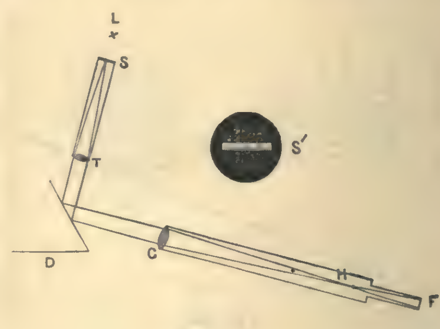


Fig. 24.

is blackened. This disc is fitted on to one end of the tube ST at S; and at the other end is a lens, T, whose focal length is just the length of

the tube. The scale, S, is illuminated by a light, L, placed behind it; and by slightly drawing out or pushing in the cap to which the scale is attached, the rays are made to emerge from the lens T, so that, after being reflected by the face of the prism, they are focused at H. Of course the direction of the scale-tube and that of the telescope must be equally inclined to the reflecting face of the prism, and therefore the former is movable round the same centre as the telescope, and in the same plane. The next figure gives a view of a complete two-prism spectroscope, and the use of its various parts will be readily understood.

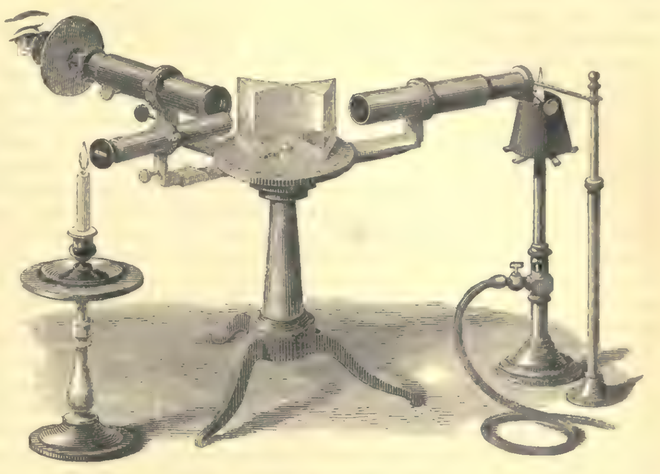


Fig. 25.

When the solar spectrum is examined with such an instrument, the positions of the dark lines are as shewn in fig. 26; but a more powerful instrument reveals the existence of several thousands. Fraunhofer mapped 576, and designated the principal ones by the letters A, B, C, D, E, F, G, H, by which designations they are still known. Their positions are determined either by stating the index of refraction for each line, or, which amounts to the same thing, the length of the ethereal wave which produces each ray. The latter method is preferable, as being independent of the nature of the prisms employed; thus the wave-lengths which would produce rays at A and the first thick line of the group H are respectively 7604 and 3968, the unit being the thousand-millionth part of a mètre. Suppose, now, our source of light to be an incandescent gas or vapour, which may be effected by exposing a substance to a heat which first volatilises it and then burns the vapour. The pale flame of a Bunsen gas-lamp will serve to volatilise and burn many substances. We find that not only do the spectra consist of isolated bright lines, but that each substance has a line or set of lines peculiar to itself. Burning sodium vapour gives two bright lines identical in wave-length, and therefore, when using the same prism, in position with the two dark lines, D, of the solar spectrum. When the electric spark is passed through a closed tube containing hydrogen, three bright lines, exactly corresponding to C, F, G, are obtained. So certain are the results, that after we have mapped the bright lines of each substance, we can tell, on looking at

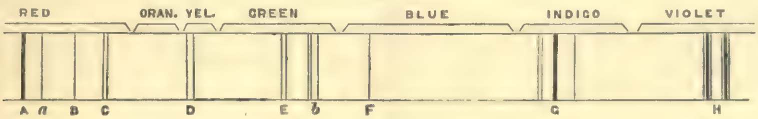


Fig. 26.

any such spectrum, what the burning substance must be. If two or more different bodies be burning together, the different sets of lines are seen at the same time, and no line of any one set interferes or coincides with a line of another. It will now be seen how readily this method lends itself to chemical analysis, for if in the spectrum of any compound substance we observe the lines of a particular element, we are certain that that element exists in the compound. And so delicate is this mode of analysis, that if a single grain of soda be dissolved in 2500 gallons of pure water, it can be infallibly detected. Again, if we find in a spectrum bright lines that have not previously been observed, they indicate the presence of a new element. In this way, Bunsen discovered the two new elements, cæsium and rubidium; Crookes, thallium; and Reich and Richter, indium. The connection between the dark lines of the solar spectrum and the bright lines of the elements was first shewn clearly by Kirchhoff in the year 1859. By allowing sunlight to enter one half of the length of the slit of his spectroscope, and the light from a sodium flame the other half, he not only shewed that the dark lines, D, of the former coincided perfectly with the bright lines of the latter—a fact which had frequently been asserted before—but he went much further. Having the continuous spectrum of the lime-light in one part of the field of view of his telescope, and the two bright lines from burning sodium immediately above it, he found that when the lime-light shone *through* the burning sodium vapour, the two bright lines were instantly converted into two dark lines in the very same place. He explained this by supposing that burning sodium vapour which could emit light waves of a certain length, could also absorb precisely those waves, when waves of all lengths were sent through it. He found the same thing to hold for many other substances which he tried, and was

led to enunciate the important law, that *all bodies which at a certain temperature can emit light rays of a certain class, can also absorb the same rays at that temperature.* The rays which are absorbed must have come from an incandescent solid or liquid at a higher temperature than the vapour. From this law it at once follows, that dark lines in a spectrum are produced by absorption, and that the position of the dark lines indicates what must have been the absorbing vapour. Now, when iron is volatilised and burned in the electric light, its spectrum is found to consist of several hundred bright lines, and Kirchhoff had mapped 460 of these. He also found that for every one of these bright lines, a dark line corresponded exactly in the solar spectrum. Hence the conclusion was inevitable, that the sun's light must have passed through vapour of iron, and that this iron must exist either in the sun's atmosphere or in that of the earth. The latter supposition cannot be correct, else the spectra of all the stars should contain the iron absorption bands, which they do not; therefore we are driven to the conclusion that iron exists in the sun's atmosphere. In the same way it is found that many of the chemical elements with which we are familiar on the earth's surface exist also in the sun. In addition to iron, there are found copper, zinc, nickel, magnesium, hydrogen, sodium, cobalt, and several others; but not gold, silver, lead, mercury, antimony, or potassium. The spectroscope has also revealed to us something of the chemistry of the stars and of the far-distant nebulæ; we have convincing evidence that the fixed stars are burning suns, somewhat like our own, but each surrounded by its own absorbing atmosphere. Thus Aldebaran, the brightest star in the constellation of Taurus, is known to contain sodium, magnesium, hydrogen, iron, and some other terrestrial elements; while Betelgeux, a bright star in the shoulder of Orion, contains sodium, magnesium, and iron, but not hydrogen.

THE TELESCOPE.

By means of a concave mirror, or a lens, the image of any object can be formed; and the size and position of the image depend on the distance of the object, and the focal length of the mirror or lens. If the object be at a great distance, the image is formed at the focus, and is of less actual size than the object, although it is seen subtending the same angle by an eye at the centre of the mirror or lens. It is thus impossible to have an enlarged image of a distant object by means of a single mirror or lens; but the image near the eye can be magnified by using a magnifying lens or eye-glass. This is the simple principle of the *telescope*, or instrument for *seeing at a distance.* The telescope is a *reflecting* or a *refracting* one, according as the image is formed by reflection from a polished surface, or refraction through a lens. Let O and *e* in the diagram be the centres of the object-glass and eye-glass, which are supposed to be mounted in cylindrical tubes, that of the eye-glass sliding within the other, so that the distance of the lenses may be slightly varied. The line joining O*e* is called the axis of the telescope. If the axis of the telescope be directed to the centre of a distant object, the parallel rays from the upper part of the object, after refraction by the lens O, are brought to a focus at the point *a*, O*a* being the focal length of the lens. An inverted image, *ab*, of the object is thus formed; and if this image be in the focus of the eye-glass, *e*, the rays from every point of it, as *a*, will, after refraction, emerge parallel to *ae*, and will be fit for vision by the eye at E, which will thus see the

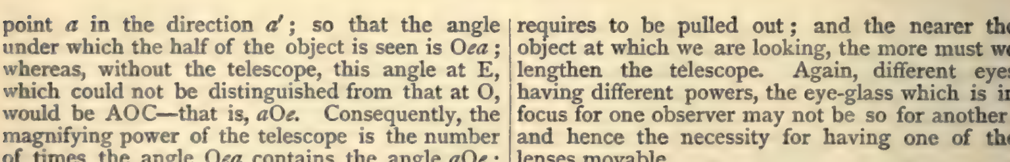


Fig. 27.

point *a* in the direction *a'*; so that the angle under which the half of the object is seen is O*ea*; whereas, without the telescope, this angle at E, which could not be distinguished from that at O, would be AOC—that is, *a*O*e*. Consequently, the magnifying power of the telescope is the number of times the angle O*ea* contains the angle *a*O*e*; that is, without sensible error, the number of times the line O*a* contains the line *ea*, or the number of times the focal length of the object-glass contains that of the eye-glass. Suppose, for instance, the object-glass had a focal length of 5 feet, and the eye-glass of 1 inch, the magnifying power would be 60; that is, a line would appear 60 times longer, a surface 3600 times greater, and a solid 216,000 times greater. If the distance of the object from the telescope be not great enough to allow us to consider the rays coming from a point in it parallel, the image is formed at a distance from O, a little greater than O*a*, and the eye-tube requires to be pulled out; and the nearer the object at which we are looking, the more must we lengthen the telescope. Again, different eyes having different powers, the eye-glass which is in focus for one observer may not be so for another; and hence the necessity for having one of the lenses movable.

To find the *field of view* of the telescope, let us draw a straight line from O to *d*, the extreme edge of the eye-glass, cutting the image in *b*. Then of all the rays falling on the object-glass, and converging to *b*, to form this point of the image, the half (namely, those passing through the lower half of the object-glass) will pass above *d*, and the eye will see the point *b* by half-pencils of light. Taking this as the boundary of the field of view, the angular diameter of the field is twice the angle *d*O*e*; that is, the angle under which the eye-glass would be seen from the centre of the object-glass. As the telescope just described

gives inverted images of objects, it is well enough adapted for celestial observations, in which this inversion is of no moment, but not at all for terrestrial observations. But by introducing a convex lens, or more frequently a combination of convex lenses, to produce an inverted image of the first image, and then magnifying this by a suitable eye-piece, the terrestrial telescope is produced, which is called an achromatic one, if the object lens be achromatic.

The reflecting telescope differs from the refracting, primarily, in having the image formed by reflection from a concave mirror; and secondarily, in requiring an arrangement for throwing the image out of the axis of the telescope, as the head of the observer, being on the same side of the mirror as the object, would obstruct the light. In the Newtonian reflector, a small plane mirror is placed in the axis of the telescope, at an angle of 45° with it, and rather nearer the mirror than its principal focus. The rays from a distant object, only a small number of which are obstructed by the plane mirror, are reflected by the large mirror, so that they would form an image in its principal focus, but striking on the small mirror, they are turned through a right angle, and the image is formed at the side of the tube. The tube is perforated at this place, and a small tube carrying the eye-glass is inserted at right angles to the large tube. As each reflection is attended by a partial loss of light, Sir William Herschel dispensed with the small mirror, by slightly tilting the large mirror, as at *mn* in the diagram,

Fig. 28.

and thus throwing the image to the side of the tube at *a*, where the eye-tube is placed. In both forms of the reflecting telescope, the magnifying power and the diameter of the field of view are calculated exactly as in the case of the refractor; but for all telescopes, they may be found experimentally, and with sufficient accuracy, as follows. Look with one eye through the telescope at an equally divided scale, placed at a distance (a brick-wall will generally suffice), and count the greatest number of divisions visible; then, with the other eye looking along the telescope, count the number of divisions in the same length: the number of times this latter number is contained in the former is the magnifying power in diameters. For the field of view, select from an atlas of the stars, or a celestial globe, a star which is on the equator, or nearly so; and directing the telescope to it, find how many seconds it takes to traverse the widest part of the field; then each second of time will correspond to 15 seconds of arc. For example, if the star remains visible for 60 seconds, the diameter of the field of view is 900 seconds of arc, or quarter of a degree.

THE MICROSCOPE.

The microscope, or instrument for viewing small objects, may be either simple or compound. The simple microscope consists of a single convex lens, of short focal length, which magnifies an object by enabling the eye to view it at a less distance than it could do without the lens; and its magnifying power is the number of times its focal length is contained in the least distance of distinct vision, which is, on the average, about ten inches. Thus, a quarter-inch lens will magnify about 40 diameters. The compound microscope consists essentially of an object lens, or combination of lenses to form a magnified image of the small object, and an eye-glass to magnify this image, as in the telescope. An additional lens, called the field-glass, is, however, always introduced between the other two, for a reason that will now be explained. Let *pq* be the minute object placed in front of the achromatic combination, A, which acts like a single lens. The pencil of rays diverging from *p* would be brought to a focus at *p'*, the line *pp'* passing through the centre of A; but the field-glass, F, being interposed, the pencil is brought more quickly

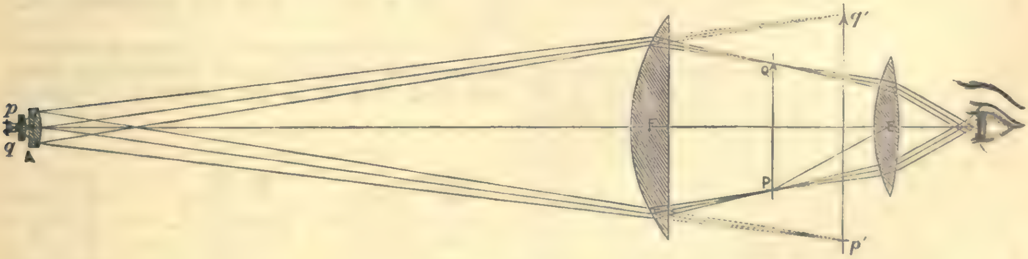


Fig. 29.

to a focus at P. Similarly, the pencil from *q* is brought to a focus at Q instead of *q'*, and an inverted image, PQ, is formed of *pq*. The image PQ being in the focus of the eye-glass E, a pencil from any point of it emerges from E parallel to the line joining the point with E, and the eye sees a highly magnified image in this last direction. The use of the field-glass is thus to cause the pencils, by which each point of the image is formed, to converge to the axis of the microscope, so that a more manageable eye-piece can be used. The magnifying power of the microscope is that of the combination, A, multiplied by that of the eye-glass, E, if we neglect the small diminution caused by the field-glass. If the distance, A*p'*, be 12 inches, and A*p* the sixth of an inch, the image *p'q'* is 72 times the size of *qp*. And if the magnifying power of E be 10, the

microscope magnifies 720 diameters. Good instruments are usually furnished with three eyepieces of different powers, and five or six object combinations, of focal lengths varying from one inch to the twelfth of an inch (or less), so that magnifying power may range from 20 to 2000 diameters.

INTERFERENCE, DOUBLE REFRACTION, AND POLARISATION OF LIGHT.

Interference.—Suppose that in consequence of a disturbance, a series of *up-and-down* waves is propagated through an elastic medium, and that, from a second disturbance, another set of the same wave-length is also propagated through it; it is easy to see that the total disturbance at any point will depend on the state or *phase* in which each wave reaches it. If the crests of both waves reach the point at the same time, it will be displaced through a distance equal to the sum of the separate displacements; and as both waves travel at the same rate, the effect is the same as if one set of larger waves were passing. But if the crest of the first wave should reach the point along with the hollow of the second, the total displacement is the difference of the two; and if these are equal, the point remains at rest. In these cases, the waves are said to *interfere* with each other; and we see that one wave will absolutely destroy an equal one, if their phases differ by half a wave-length, or a length and a half, two and a half, &c. As light consists of waves, it should be possible for two lights to produce darkness, and this strange conclusion has been established by direct experiment. Let A and B be two small holes, very close together, in the shutter of a darkened room, through which a homogeneous light is

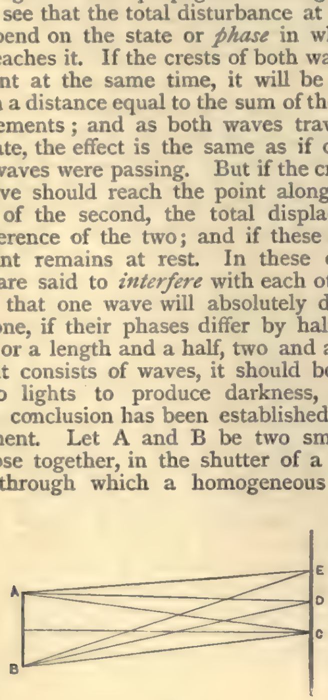


Fig. 30.

admitted. If a screen, of which EC is the section, be held at a suitable distance to receive the diverging pencils, it will be found that the intensity of the light in EC is not uniform, but that there will be a bright spot at C, which is equally distant from the two holes, a dark spot at D, a white spot at E, and so on. These spots on the section EC are of course bands on the screen; and if one of the holes, as B, be stopped, the bands suddenly disappear; if it be opened again, they reappear. Thus, the addition of more light to D has caused darkness. By careful measurement, it has been found that the difference between the paths AD and BD is half a wave-length; between AE and BE, two halves; and so on. If the compound light of the sun be used, the blue, which has the smallest wave-length, occupies a different position at E from the red, whose wave-length is greatest; and the other colours lie between. There is thus a coloured band at E, with the blue lowest; and these bands are repeated until the colours of one band are mingled with those of the next, and the screen is white.

Double Refraction.—If a ray of light be allowed to fall on a rhomb of Iceland spar, instead of being refracted as in glass, it is split up into two rays of equal intensity, one of which obeys the ordinary law of refraction, and the other does not. This property of double refraction belongs to all crystallised minerals, except those of which the cube is the fundamental form, or, more generally, to all bodies whose density differs in different directions. Thus, a cube of glass can be made to refract doubly, by compressing it strongly in one direction. The two rays into which the single one has been split up do not at first seem to differ from each other, or from common light; but if they be allowed to fall on a second rhomb, a remarkable difference is observed. If, for shortness' sake, we designate the ordinary and extraordinary rays by the letters O and E, we find that though in general both O and E are split up into two others, OO, OE, EO, EE, the two components are no longer of the same intensity, and that in certain relative positions of the crystals, one disappears altogether. If the two crystals are in similar positions, O produces only OO, OE having quite disappeared, and E produces only EE, EO having disappeared. If the second crystal be turned through 90°, OE and EO alone remain. Thus, not only have the two rays, O and E, acquired properties with respect to space (that is, got *sides* or *poles*), but these properties are the same for the two rays with respect to two planes at right angles to each other. The two rays are said to be polarised, and their planes of polarisation are perpendicular to each other.

Polarised Light.—Some crystals, after separating the two rays, absorb one of them, as tourmaline, which suppresses the ordinary ray. There are other ways of obtaining one ray without the presence of the other, but this method will be assumed for simplicity. If we wish to examine any pencil of light to ascertain whether or not it is polarised, we must use a double refracting rhomb, or such an analysing plate. If we find that in a certain position of the analyser, one ray is extinguished, the beam was wholly polarised; but if the intensity was only weakened, then the polarisation was partial.

Some of the most splendid phenomena in optics are produced when bodies are examined by polarised light. Let T be the polariser, a plate of

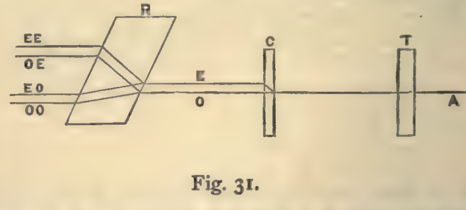


Fig. 31.

tourmaline cut parallel to its axis; R, the analysing rhomb; and C, a doubly refracting crystal, which we are examining. A ray of common light, A, after passing through T, is polarised, its companion ray having been quenched. B is split up by C into E and O, polarised at right angles to each other, and differing in phase, E being retarded more than O. If E and O were common light, they

would interfere with each other, but light polarised in one plane cannot interfere with that polarised in the plane perpendicular to it. On passing through the analyser, R, the two rays, O and E, are subdivided into four, as in the figure; the two, EE, OE, which emerge together, being polarised in the same plane, which is at right angles to the plane of the other pair, EO, OO. As the members of a pair are in different phases, they will interfere with each other, and colours will be produced by one pair which will be the same as would be produced by the other pair if their plane could be turned through 90°; or, in other words, the colours of one pair are complementary to those of the other. If the analyser be made to revolve round the line AB as an axis, all possible gradations of colour are produced. The phenomena of polarised light have proved that the waves of light are not backward and forward waves, like those of air, but transversal —that is, up and down, like waves of water, or from side to side. The polarisation of light is the resolution of the vibrations of each particle into two, at right angles to each other, which produce waves travelling in different directions. If one of these can be isolated from the other, the light is said to be polarised.

SOUND.

Sound (Latin, *sonitus;* French, *son;* German, *schall*) is the name given to the sensation produced in the organs of hearing by the vibrations of the air or other elastic medium with which they are in contact. The name is also applied to the physical cause of the sensation; and that branch of Natural Philosophy which treats of the laws of sound is called Acoustics, from a Greek word meaning *to hear*.

That the existence of an elastic medium is necessary for the production of sound, is proved by the fact, that a bell rung in the exhausted receiver of an air-pump cannot be heard. But many other substances besides air can convey sound. Divers below water can hear even a very feeble sound if it is produced under the water. And it is well known that bars of wood and metal transmit sound with great distinctness. If the ear be placed at one extremity of a long piece of wood, it will readily hear a slight tap made at the other end, much too feeble to be conveyed the same distance by the air.

Air, however, is the medium by which sound is generally conveyed to the ear, and the rate at which sound travels in air can be easily ascertained in the following manner. Let a cannon be fired at a considerable distance from an observer, who counts the number of seconds between the time of his seeing the flash and his hearing the report. The velocity of light is so inconceivably great, that we may, without appreciable error, suppose that he sees the flash at the very instant it is produced. The number of seconds is therefore the time that sound takes to travel the distance between the cannon and the observer, and if this distance be measured, the velocity of sound in air is determined. It has thus been found to be in dry air at the freezing-point about 1082·7 feet per second, or rather less than 12½ miles a minute; but the rate depends slightly on the temperature of the air, being greater as the temperature is higher. Thus, at 59° Fahrenheit the velocity is 1112·2. Again, when we know the rate at which sound travels, and the time it has taken to reach our ear, we can find the distance at which it was produced. For instance, if, after seeing a flash of lightning, we count 3½ seconds before hearing the thunder, we know, if the temperature of the air at the time is 59° F., that the discharge has taken place at a distance of 3½ times 1112·2 feet, or 3892·7 feet. It is evident that it cannot be the same particles of air that are set in motion by the sounding body which strike the ear to produce the sensation of sound, for this would require the air particles to be transported at the rate of 12½ miles a minute, or 750 miles an hour, which is six times faster than the rate of the most violent hurricane that ever blows. The motion is a vibratory one, so that the disturbed particles move backwards and forwards through a small distance, and similarly disturb the neighbouring particles. This is a wave-motion, in which the displacement of each particle is in the direction in which the wave travels, whereas in waves on the surface of water, and in the ethereal waves which constitute light, the particles move at right angles to the direction in which the waves travel. Sound-waves are therefore waves of condensation and rarefaction. And the distance between one point of greatest condensation and the next, is the wave-length. The range through which each particle moves backwards and forwards is called the amplitude of the vibration, which is quite independent of the wave-length. The extent of this range will manifestly be increased, if the exciting cause of the atmospheric disturbance be greater, and the intensity or loudness of the sound will be greater. Thus, if all other conditions remain the same, the loudness of sound is measured by the amplitude of the vibration, and is proportional to the square of this amplitude, so that a double amplitude gives a fourfold intensity. When a series of waves is propagated from any point, the amplitude diminishes in the same proportion as the distance increases, and thus the intensity of sound diminishes as the square of the distance increases.

The air-waves which produce the sensation of sound are excited by delivering a blow, or a series of blows, to the air. If a bell be struck by a hammer, its particles are thrown into a state of vibration, as we may convince ourselves by lightly applying our finger to the edge, and the vibrating particles give rapid blows to the air, and thus produce sound-waves, which are propagated in all directions. In this case, the sound is *musical;* but if a table be struck by the hammer, its vibrations cease almost immediately, and a single sound or *noise* is the result. Thus we see that a musical sound is produced when a definite noise is repeated often enough at equal intervals of time. This statement may be verified by holding the edge of a card so that it may be struck by a revolving toothed wheel. When the wheel revolves slowly, a series of noises is produced; but when it revolves so fast that the noises melt into a continuous sound, a musical note is the result. Further, the pitch of this note is higher, the faster the wheel revolves; and if the speed can be sufficiently increased, the pitch becomes too high for the ear to appreciate, and the notes become inaudible. There

is also a lower limit below which grave sounds cannot be heard, and although these limits will be different for different ears, still, for the average ear, only those sounds are audible which are made by more than 32, and less than 72,000 vibrations per second.

Like waves of light, sound-waves can be reflected by plane and curved surfaces, and also refracted by suitable lenses. When the sound-waves are reflected by a plane surface, such as a smooth wall or the flat face of a rock, an *echo* is produced, if the reflecting surface be at a sufficiently great distance. The necessity for this proviso may be thus shewn. However short a time a sound may last, the impression it produces on the ear remains a perceptible time, which is about the tenth of a second; so that, if two sounds follow each other in less than the tenth of a second, they interfere with each other. In the tenth of a second, sound will travel, at ordinary temperatures of the air, about 111 feet; and if the reflecting wall be less than 55½ feet distant from the point whence the sound proceeds, there will be less than the tenth of a second between the time of the original sound leaving the point, and the reflected sound returning to it, and a confusion of sounds is produced with no echo. It is this confusion of sounds that interferes with hearing in churches, lecture-rooms, and other large buildings that are not built on acoustical principles. A partial remedy for the defect consists in weakening the reflection by destroying the evenness of the surface, as by suspending curtains at intervals along the walls. If the wall is exactly 55½ feet distant, there is just sufficient time between the production of the sound and the arrival of the echo for the ear to discriminate them as two separate sounds, so that an echo cannot be distinctly heard unless the reflecting surface be at a distance not less than 55½ feet. The number of syllables that an echo can repeat is the number that can be pronounced in the time that sound takes to travel to and from the reflecting surface. The celebrated echo at the tomb of Metella, wife of Crassus, near Rome, was said to have repeated distinctly the first line of the *Æneid*, which contains fifteen syllables. If we allow three seconds as the time necessary to repeat this line distinctly, the reflecting surface must have been at a distance of 1668 feet. If the sound, after being once reflected, is reflected a second time, a double echo is produced; and if the reflecting surfaces be many, there is a multiple echo. One of the most interesting echoes of this kind is that which occurs on the banks of the Rhine, at the Lorlei rocks. If the weather be favourable, the report of a pistol fired on one side is repeated from crag to crag on opposite sides of the river alternately, for as many as ten or twelve times. At the château of Simonetta, in Italy, an echo between two parallel wings of the building repeats a sound thirty times. In whispering-galleries, a feeble sound made at one particular part of the building is repeatedly reflected from the smooth walls, and many of the reflected waves finally converge to another point where the sound is distinctly heard. In the dome of St Paul's Cathedral in London, a whisper at one side is heard at the other, though at all intermediate places it is quite inaudible.

That the sound-waves are refracted in passing obliquely through a medium denser than air, is clearly proved by the following experiment, first performed by M. Sondhauss. AB is a double convex bag, formed of collodion, and filled with carbonic acid gas, which is rather more than one and a half times heavier than air. A watch, W, is placed in the axis of the gas-lens, and the ear, E, of the observer is shifted backwards and forwards also in the axis of the lens, and it is found that there is one point, E, where the ticking of the watch is distinctly heard; though nearer and further from the lens, the sound is scarcely heard. E and W are therefore conjugate foci of the gas-lens, and the sound-waves have been refracted by the lens exactly as the light-waves in travelling through a glass lens.

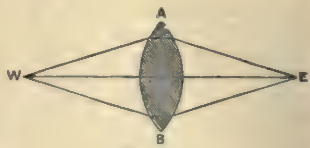


Fig. 32.

THEORY OF THE MUSICAL SCALE.

A simple musical tone, as that yielded by a tuning-fork, is produced by a continuous rapid vibration, if the number of single vibrations (the forward and the backward motions being two single, or one double vibration) fall between the limits before stated. One tone may differ from another in pitch, as the tone of one tuning-fork may be higher or lower than that of a second. The pitch, as we have seen, depends on the number of vibrations per second, or, which comes to the same thing, on the length of the wave, for as the velocity of sound is 1112 feet per second, if there are 100 vibrations per second, the wave-length is 11·12 feet. Again, the same tuning-fork may emit a weak or a loud tone; or musical tones of the same pitch may differ in intensity; and the intensity has been shewn to vary with the square of the range, or amplitude of vibration. Once more, if a pianoforte be made to yield a tone of the same pitch and intensity as the tone of the tuning-fork, we are conscious of a difference between the two tones, and this is a difference in quality, or colour, so to speak. In French, this difference is called *timbre*, and in German, *klangfarbe* (colour-tint). The cause of this difference will be explained presently.

Let us now take any note of the pianoforte, say C on the annexed scale, which is produced by 528 vibrations in a second, or 480 in the unit of time, if we make our unit $\frac{10}{11}$ of a second. If another note be yielded by 960 vibrations in the unit of time, the ear at once recognises an agreeable concordance when the two are sounded together. And similarly for any other two notes whose vibrations are as one to two. If we take two notes between these, such that their vibrations in the same time are to C's as 1½ to 1 and 1 to 1¼, we have four notes, which, when sounded together, produce a very pleasing effect, and form what is called a major chord. The lowest three of the chord have their vibrations in the proportion of 4, 5, and 6, and constitute a *harmonic triad*. Let us form two more triads from this one, by making the highest of the three the lowest of the second triad, and the lowest of


C = 528 vibrations.

the three the highest of the third triad. The numbers representing the vibrations of the second triad will be 6, 7½, 9; and of the third triad, 2⅔, 3⅓, 4; these sets of numbers having the proportion of 4, 5, and 6. In addition to our original note C, and that derived from it by doubling its vibrations, we have other six notes. And if we place the six notes between the first two, by doubling the vibrations of those below C, and halving the vibrations of the one above double C, we have the following series :

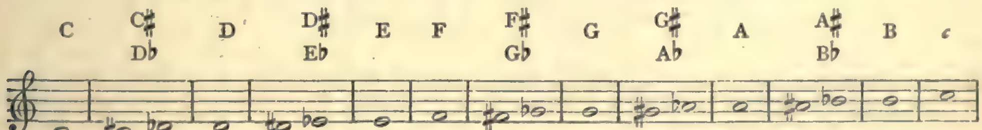
$$\begin{array}{cccccccc} 4 & 4\frac{1}{2} & 5 & 5\frac{1}{3} & 6 & 6\frac{2}{3} & 7\frac{1}{2} & 8; \\ C \end{array}$$

or, dividing each number by 4, and naming the notes by the first seven letters of the alphabet, we have :

$$\begin{array}{cccccccc} 1 & 1\frac{1}{8} & 1\frac{1}{4} & 1\frac{1}{3} & 1\frac{1}{2} & 1\frac{2}{3} & 1\frac{7}{8} & 2 \\ C & D & E & F & G & A & B & c \end{array}$$

We have now eight notes in all, forming what is called the *diatonic scale*, and *c* is called the octave above C ; G is a fifth above it, and E a third. The scale may be extended both upwards and downwards, by doubling the numbers for the right-hand extension, and halving them for that on the left, and thus a common pianoforte has a compass of seven octaves. The lowest notes of each of the three triads formed above have received special names, C being called the *tonic*, G the *dominant*, and F, the octave above the lowest of the third triad, the *subdominant*.

If, instead of making our triad consist of notes whose vibrations are as 1, 1¼, 1½, we make the ratios 1, 1⅕, 1½, the three notes form a minor triad, and when sounded with the octave of the lowest note, produce a pleasing, though somewhat melancholy effect. A scale formed from three minor triads would be a minor scale, though the minor scale in practical use is formed differently. In the ascending scale, the tonic has a minor triad, while the dominant and subdominant have major triads ; but in the descending scale, all the triads are minor. The ratio of a major to a minor third is 25 to 24, and this ratio is called an interval of a semitone. In music, it is convenient to subdivide the interval between two consecutive notes, and this is done by raising the one note, or lowering the other, by half a tone ; that is, multiplying the number of vibrations of the one, or dividing that of the other by $\frac{25}{24}$. The note formed by raising C one half-tone, or by sharpening C, is called *C sharp*, and is written C♯ ; and that by lowering or flattening D, is *D flat*, written D♭. The vibrations per second of these four notes are as the numbers $\begin{array}{cccc} 1 & \frac{25}{24} & \frac{27}{25} & \frac{9}{8} \\ C & C\sharp & D\flat & D \end{array}$; and those of C♯ and D♭ are so nearly equal that only a practised ear can recognise the difference of pitch. In the pianoforte, the same note serves for both, and the new notes introduced correspond to the black keys. As the interval between E and F, and between B and *c*, is very nearly a half-tone, it is not necessary to sharpen E or B ; and consequently the *chromatic* scale, as it is termed, is as follows :



VIBRATIONS OF STRINGS AND COLUMNS OF AIR.

If a stretched string or wire, AB, be sharply struck, or pulled aside, or agitated by a resined bow, it is thrown into to-and-fro vibrations, which give rise to a musical note. By placing the bridge, B, at different distances from A, we can vary the length of the sounding-string ; and to increase the intensity of the sound, a sounding-board, CD, which can vibrate in unison with the string, is placed below it. The blows given directly to the air by the string are too small to produce a loud sound ; but the vibrations of the sound-board being continually reinforced by those of the string, soon become appreciable, and a comparatively large mass of air is set in motion. If the bridge be successively placed at points which give vibrating lengths proportional to the numbers

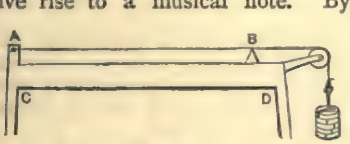


Fig. 33.

$$1,\ \tfrac{8}{9},\ \tfrac{4}{5},\ \tfrac{3}{4},\ \tfrac{2}{3},\ \tfrac{3}{5},\ \tfrac{8}{15},\ \tfrac{1}{2},$$

all the notes of the diatonic scale are produced. Therefore, we conclude that :

(1.) *When the length of the string alone varies, the number of vibrations in a given time is inversely as the length.* After a given note has been sounded, let the stretching-weight be increased four times, and it will be found that the new note is the octave above the last, or that the number of vibrations is doubled. If the two weights are as 16 to 25, the two notes form a major third, or the vibrations are as 4 to 5. The second law is therefore :

(2.) *When the stretching-weight alone varies, the number of vibrations in a given time is as the square root of the weight.* Let two strings of the same material, length, and tension, be placed side by side, but let the diameter of the second be half as much again as that of the first, or the double of it, and it will be found that the note of the second is a major fifth, or an octave below that of the first, or that the number of vibrations in a given time are as 3 to 2, and 2 to 1. So that the third law is :

(3.) *When the diameter of the string alone varies, the number of vibrations in a given time is inversely as the diameter.* And the fourth law is :

(4.) *When the density of the string alone varies, the number of vibrations per second is inversely as the square root of the density.* When the string AB is vibrating, and giving out its primary note, if it be lightly touched in the middle, it now

vibrates in two halves; and from the rapidity of the motion, the eye sees the string in its two extreme positions at one and the same time. The point C is called a *node;* and the parts AC, BC are called *loops*, or *ventral segments*. If we touch

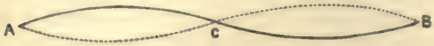


Fig. 34.

the string at a third or a fourth of its length, it divides itself into three or four loops. The notes formed by a string vibrating in one, two, three, four, &c. loops, are respectively the primary or fundamental note, its octave, the fifth above the octave, the octave above the octave, &c.; and the whole series are called the *harmonics* of the fundamental.

The actual motion of a vibrating string is not so simple as the motion just described, but added to the primary vibration, there are a number of partial vibrations, of smaller intensity, and corresponding to the half, third, fourth, &c. parts of the string, so that a simple note is never heard, unless accompanied by several of its harmonics. The undisciplined ear cannot at first detect the complexity of a musical note, but careful attention will soon prove the fact. The existence of the harmonics may also be demonstrated by partially quenching the fundamental tone. For this purpose, after the string has been sounded, if we touch its middle point with a feather lightly for a moment, the fundamental is so much weakened that the octave is clearly heard. But the most satisfactory analysis of musical sounds has been made by Helmholtz, who, for this purpose, contrived an instrument which he called a resonance globe. This is a globe with two openings, *s* and *t*, of which one, *s*, wide and cylindrical, is turned towards the sound, and the other, *t*, has an india-rubber tube attached to it, which is applied to the ear. Like the sounding-board, the air in this cavity will respond to a certain note, so that if several other notes be sounded along with this particular one, the resonator will strengthen its own note only, and the ear will hear it distinctly to the exclusion of all the others. Consequently, by means of a series of such resonators, each one of which responds to a note of the diatonic scale, and its octaves, a given note can be analysed. And it is found that every note is mingled with many of its harmonics. By means of the same resonators, Helmholtz has succeeded in explaining the *timbre* or quality of musical notes. He has proved that the difference between the same note sounded on different instruments, say C of the violin and C of the pianoforte, depends solely on the different intensities of the harmonics which accompany the primary note.

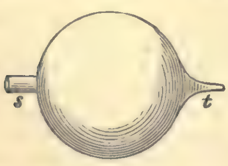
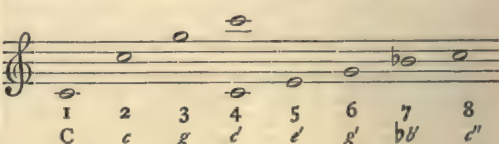


Fig. 35.

A column of air may be made to vibrate, and emit a musical sound, by taking a tube, *ab*, open at both ends, and blowing at one end, *a*, across and a little downwards. When such a tube is made to yield its lowest or fundamental note, the air particles within it vibrate, so that those at *a* and *b* are most agitated, their relative distances not being much altered; while those at the middle point, *c*, are not displaced at all, the neighbouring particles alternately approaching them, and receding from them. The distance between a point of greatest disturbance and a node, or point of rest, that is, *ac* on the figure, being quarter of a wave-length, it is clear that the wave-length of the fundamental note is twice the length of the tube. The number of vibrations in a second is found by dividing the distance which sound travels in a second by the wave-length. Supposing the note C produced by 264 vibrations in a second, and the velocity of sound at ordinary temperatures to be 1112 feet, it is easily found that the length of an open pipe, of which C is the fundamental note, is 2·1 feet. By blowing more strongly into the pipe, it is easy to produce a note whose wave-length is half of that of the fundamental note; and consequently, the new note is the octave above the former one. In this case, there is a node at *d* half-way between *a* and *c*, and another at *e*, the middle of *cb*. Again, no note between the fundamental and its octave can be obtained from the pipe, for, as the open ends, *a* and *b*, must always be points of greatest disturbance, no first node can lie between *c* and *d*. The next possible notes are produced when the first node lies at a distance from *a* of $\frac{1}{6}$, $\frac{1}{8}$, $\frac{1}{10}$, &c. of the length of the pipe; and then the wave-lengths of all the notes that can be given by such a pipe are as the numbers 1, $\frac{1}{2}$, $\frac{1}{3}$, $\frac{1}{4}$, &c. or the numbers of vibrations in a given time are as 1, 2, 3, 4, &c. Of these notes, which are called the harmonics of the pipe, the first eight are here represented, but the last four of the series are, for

Fig. 36.



convenience, written two octaves lower than they should be. As with vibrating strings, so likewise with vibrating columns of air, a pure note is never sounded alone, but each one is always accompanied by some of its harmonics.

If the pipe containing the column of air be closed at one end, the conditions which every vibration must fulfil are, that at the open end there must be a point of greatest disturbance and at the closed end, a node. The fundamental note of such a pipe must be one of which the quarter wave-length is that of the pipe, and is, therefore, an octave below the fundamental note of a pipe, of the same length, open at both ends. There cannot be a node in the middle of the closed pipe, for this would require *b* to be a point of greatest disturbance. There may be nodes at $\frac{1}{3}$, $\frac{1}{5}$, $\frac{1}{7}$, &c. of the length from *a*, so that all the harmonics are included in the series 1, 3, 5, 7, &c.

Fig. 37.

MAGNETISM AND ELECTRICITY.

MAGNETISM.

ANCIENTLY, there was discovered in Magnesia, in Asia Minor, a kind of iron ore which had the remarkable property of attracting other kinds of iron or steel. This ore afterwards received the name of *loadstone*, but from Magnesia we derive the terms *magnet* and *magnetism*.

Not only does the loadstone possess this power of attracting iron itself, but it can communicate its virtue to steel. A bar of well-tempered steel, if repeatedly rubbed by it, acquires exactly similar properties, and is termed an *artificial magnet*, while the other is called a *natural magnet*. In point of strength and convenience, artificial magnets are far superior to natural ones, and are therefore more commonly used.

If we take a bar of steel, which has been thus rubbed by a loadstone, and to which the name of *bar-magnet* is usually given, and scatter iron filings over it, they will adhere in tufts at both ends, but none will be found at the middle of the bar. Or we may put the magnet under a sheet of pasteboard, and sprinkle the filings over the sheet. We shall then find the small particles of iron arrange themselves in beautiful curved lines round both ends of the magnet. It appears from this that the chief power of the bar lies at the two ends, round which, as centres, the curves are formed.

These centres of magnetic force are called the *poles* of the loadstone or magnet, from another peculiar property which they are found to possess. If a magnetic bar be suspended by a thread, or be delicately poised on a pivot, it will not rest till it has settled in one position, which is in a direction nearly north and south. If moved from this position, it returns to it again, the *same end* always turning towards the north. That end which so points to the north is called the north pole of the magnet, and the other its south pole.

We can never have a magnet with only one pole. The two are always found together, and are opposite both in their properties and position. If we break a magnet in two, we do not have two pieces, one all north pole, and the other all south; but we have two complete magnets, and this however many times we break the bar. To this twin exhibition of force residing in opposite sides of a body is given the name of *polarity*. We shall find that it is not peculiar to magnetism, but is a feature of all electric phenomena. Sometimes, indeed, we have in the same bar more than *one pair* of poles; but this is owing to some irregularity of the steel temper, or of the mode in which the magnetism has been communicated. When more than one pair of poles occurs in a magnet, they are called *consecutive* points. They render a magnet practically worthless.

The action of the poles of one magnet on those of another is remarkable. If we bring two north poles together, they repel each other; or, if we bring two south poles together, they do the same. But if we bring a north near to a south pole, they attract each other powerfully, and cling together. From this simple experiment we deduce the two general laws of magnetic action: *Like poles repel each other: unlike, attract each other.* It is thus very easy to tell the north and south pole of any magnet. We have simply to try its action on a needle suspended so as to point north and south.

Magnetic Induction.—A bar of soft iron has of itself no power to attract iron filings, or another piece of iron. In presence of a magnet, however, it instantly assumes this power. When we suspend from, say, the south pole of a magnet a short rod of iron, its free end attracts filings, just as the magnet would do, and the iron has become, in every way, like a magnet. It has two poles, that end being a north pole which is next the south pole of the magnet. The same thing is seen, though in a less powerful degree when the magnet is simply brought near to the soft iron. But the magnetisation of the iron, though perfect, is merely temporary. The moment we take away the magnet, its magic power is gone, and the filings drop off.

This action of a magnet on soft iron, communicating to it a temporary magnetic polarity, is termed *induction*. All bodies, as we shall see under *diamagnetism*, are magnetic—that is, influenced by magnetism in one way or another. But induction proper, by which two magnetic poles are excited, is confined to iron and its varieties. Even here there is a remarkable contrast. The influence of a magnet on tempered steel is very different from that on soft iron. Steel will not assume the polar state at once, but only after repeated friction with a magnet. Yet, once magnetised, it retains its polarity with equal stubbornness. The cause of this is not well understood; but it is usually ascribed to the presence with the particles of steel of a *coercitive force*, as it is called, which resists equally the communication and the abstraction of the magnetic state.

Induction, or the action of a polarised body inducing a similar polarised state of another body in its vicinity, is not confined to magnetism, but appears to be manifested in every case of polarity. We shall see, under Electricity, a similar influence possessed by a body electrically excited or polarised.

Forms of Magnets.—In place of the bar shape, it is very often more convenient to give the magnet the form of a horse-shoe, so that both poles may be brought to act on the same object. When

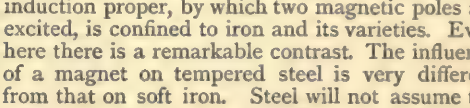


Fig. 1.

powerful magnetism is desired, it is better not to increase the mass of the magnet, but to form a *magnetic magazine*, or *compound magnet*. This

is done by magnetising separately a number of similar bar or horse-shoe shaped pieces of steel, and binding them together with the like poles lying the same way. Fig. 1 shews the mode of arrangement of a compound bar-magnet. The bars are bound by a brass screw or frame to a piece of iron at each end, in which the several poles have their magnetism concentrated. Fig. 2 represents a compound horse-shoe magnet, with its armature attached. This armature or keeper must be used with all magnets, to prevent the loss and ultimate disappearance of their magnetism. It is simply a piece of soft iron placed across the opposite poles of a horse-shoe magnet, or of a pair of bar-magnets. Any magnet, not shielded by its armature, has its polarity disturbed and even destroyed by the action of the earth, which is itself an enormous magnet. The soft iron is made, by induction, an exact counterpart of the magnet, and the power of the permanent poles is in this way even increased, for a much greater weight can be suspended from the armature than the single poles can sustain.

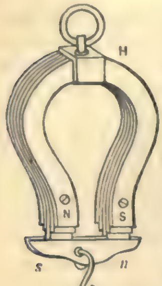


Fig. 2.

Magnetisation.—There are several processes by which a bar of steel may be magnetised. The simplest way is to pass one pole of a strong magnet from end to end of the bar several times, and always in the same direction. In this case the magnetism of the end first touched will be the same as that of the rubbing pole.

A somewhat better way is to rub the steel bar from the middle to one end with one pole, say the north, of the magnet, and then from the middle to the other end with the south pole. Each half is to be rubbed the same number of times, and the end rubbed by the *north* pole becomes a *south* pole.

Another, and a very accurate method is that shewn in fig. 3, which is employed for magnetising needles. It is called the method by *Divided Touch.* The bar, *ns*, to be magnetised, is placed

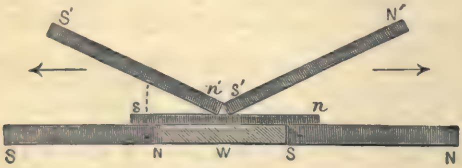


Fig. 3.

on a piece of wood, W, with its ends resting on the opposite poles of two strong bar-magnets, NS and SN. Two rubbing magnets are placed, with their opposite poles together, at the middle of *ns*, and making a small angle with it. They are then moved away from each other to the ends of *ns*, and brought back in an arch to the middle again. If this is done a few times, the bar is fully magnetised, the positions of the various poles being indicated by the letters in the figure.

For horse-shoe magnets, the usual method is to place the inducing magnet upright on the magnet to be formed, with an armature across its ends, as drawn in fig. 4. It is then moved from the ends to the bend, or in the opposite way, and

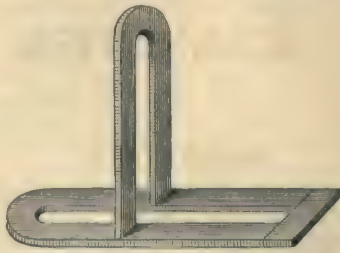


Fig. 4.

brought round again in an arch to the starting-point.

Other methods of magnetising steel, which do not require the aid of another magnet, are furnished by the magnetic power of the earth, and by the galvanic current. But these will be explained afterwards.

Magnets, when freshly magnetised, have often more magnetism than they can retain. In that case, they gradually fall off in strength until they reach a stationary point, when they are said to be *saturated.* The strength of magnetism that can be imparted permanently to any magnet, or its saturation point, depends on the quality and temper of its steel. If a magnet has got weakened, its strength may be gradually restored by hanging weights to its armature, and increasing them gradually from time to time. On the other hand, by repeatedly detaching the keeper abruptly, we weaken the power of a magnet, and in this way it is very easy to reduce one above saturation to its fixed strength. It may be remarked generally, that whatever disturbs the molecular condition, or internal state of the particles of a magnet, affects its power. A red heat will deprive it of all traces of magnetism, and a blow, or a number of blows, may do the same, or may even change the poles.

Theory of Magnetism.—The best known theory of magnetism supposes that there are two magnetic fluids existing in the substance of the magnet, and adhering to it. Each kind of fluid repels itself, but attracts the other kind. In an unmagnetised body, the two fluids are supposed to be mixed up together, and so to counteract each other's effects. Magnetisation consists, according to this view, in separating the two fluids to opposite sides of the body, or to opposite sides of each particle of the body.

Another more recent and more plausible theory regards a magnet as an assemblage of minute permanently magnetic particles, with their similar poles all lying one way. We have seen that, though a magnetic bar be broken into fragments, each piece is a perfect magnet. This fact is supposed to be a strong argument in favour of the latter theory. To magnetise a body is to throw its particles into a state of *regular* polarity, its previous want of magnetism being due to the want of this *regularity.*

Ampere's theory, which connects the phenomena of magnetism and of electricity, is another and still more novel theory, which will be explained under Electro-magnetism.

Diamagnetism.—It had been known since the beginning of this century that the metals nickel and cobalt were feebly magnetic, and could be

attracted by a strong steel magnet. But the effect of magnetism on other bodies was unknown till the discovery of an unlimited magnetic power in the galvanic current. The electro-magnet (to be afterwards described) was used in the hands of Faraday, to shew that all bodies are more or less magnetic; though, in general, the magnetism is so feeble as to be utterly insensible to the most powerful steel magnet. Faraday, in 1845, first proved that all the metals, such as gold, silver, copper, &c. as well as the liquids and gases, are influenced by the powerful magnetism of the electro-magnet. He also established, by a series of beautiful experiments, that there is a notable difference in its effects on different bodies.

If a small piece of iron wire be hung by a silk fibre between the poles of an electro-magnet (fig. 5), it will come to rest with its length in the line of the poles, *ab*, or *axially*, as Faraday termed it.

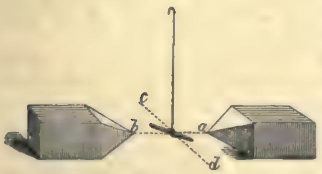


Fig. 5.

But if a small rod of bismuth be suspended in this way, it will set with its length along *cd*, that is, across the line of the poles, or *equatorially*. The reason is, that iron is attracted by both poles, while bismuth is repelled by both. Iron, and substances which behave like it, Faraday called *paramagnetic*; bismuth, and those like it, he called *diamagnetic*. Ordinary magnets are sufficient to shew the paramagnetism of iron, nickel, and cobalt; but the coercitive force of other substances is so feeble that they require a much more powerful magnetism. The following substances are found to be paramagnetic: *Iron*, *nickel*, *cobalt*, *manganese*, *paper*, *sealing-wax*, *plumbago*, *red lead*, *zinc*, *sulphate*, *shellac*, *charcoal*. These are diamagnetic: *Bismuth*, *antimony*, *zinc*, *tin*, *mercury*, *lead*, *silver*, *copper*, *gold*, *alum*, *glass*, *nitre*, *sulphur*, *resin*, *water*, *wood*, *leather*, *caoutchouc*. They are given in the order of their coercitive force. By inflating soap-bubbles with different gases, Faraday found they also were magnetic, but to a much feebler degree than any solid or liquid substances.

TERRESTRIAL MAGNETISM.

Our earth is an immense magnet, with its two magnetic poles situated *towards* the north and south ends of its axis. This is the cause that a magnetised needle, delicately poised, as shewn in fig. 6, takes up a position nearly north and south. The distances of the earth's poles are so great that their actions on the poles of the needle may be regarded as equal forces acting in opposite ways. Such forces can have no other effect than merely to turn the needle round its axis, so as to have its length in their direction. For this reason, a common steel needle, magnetised and made to swim on water, will shew no tendency to move either towards the north pole of the earth or towards the south, but will simply set in their line.

Fig. 6.

The value of the magnetic needle as a guide, in the absence of other directing marks, is obvious. To the navigator it is inestimable, and led, centuries ago, to the invention of the *mariner's compass*.

But the needle does not point *due* north and south, and the amount by which it deviates from that direction is called the *declination* of the needle. In more precise language, the *declination* is the angle between the magnetic and the geographical meridian at any place. An instrument furnished with a very delicate needle and the means of ascertaining the true meridian of a place, is called a declinometer.

It is of the utmost importance to the mariner to know the amount of this deviation of his needle, or compass, from the true north; and what makes the indications of his guide less reliable is the fact, that the declination is not the same for all places on the earth's surface. In some places, there is no declination at all—that is to say, the needle points due north. In this country, it points to the *west* of true north, while in India it is found to point to the east of it.

Charts have been drawn having these important changes accurately marked by lines traced through all places where the amount of declination is the same. These lines are called *isogonic* or *equal-angle* lines, and the charts *isogonic charts*. Looking at such a chart, we see that the needle points to the *west* of the true north in *Europe* and *Africa*, in the *Atlantic Ocean*, in the *eastern part of the two Americas*, and *the western part of Asia and Australia*. These form what may be called the western declination hemisphere, while the other parts of the earth's surface form the eastern. An irregular line of no declination separates the two hemispheres, running through the eastern continent of North America, and a corner of South America, and coming round through Australia, the west of Asia, and the east of Russia. Curiously enough, the line is slowly changing place, the Asiatic line of no declination advancing towards Europe.

Nor does the declination vary only with the place on the earth's surface, but, at the same place, it varies with the *year*, the *season of the year*, and even the *hour*. At Paris, for instance, in 1580, when observations first began to be recorded, the declination was $11\frac{1}{2}°$ E.; it gradually receded till, in 1669, it was 0°. In 1700, it had gone 8° to W. and continued its westerly sweep till, in 1814, it was as much as 22° 34′ W. Since then, it has been slowly diminishing, and it was, in 1864, down to 18° 57′ W. at Paris. In England, the greatest declination was, in 1815, 24° 27′ W.; and, in 1865, it was 21° 6′. Thus, in half a century, it has receded, in England, about $3\frac{1}{4}°$. At present, it is about 19° 45′ W.; the annual rate of decrease being about 8′.

There is also a periodical variation with the season of the year. Observations shew that, from April to July, the amount of westerly declination decreases; while, during the rest of the year, there is a slight turning to the west.

The relative position of the sun during the day also influences the needle. From three to eight o'clock in the morning, there is a gradual motion of the needle to the east of its mean position. At

eight o'clock, it begins a westerly sweep, crossing its mean position about 10 A.M. Its maximum distance to the west it reaches at 1 P.M.; when it again begins its easterly course, coming up once more to its mean position about seven o'clock in the evening.

Besides these *regular* variations of the declination, there are sudden and unforeseen disturbances, caused by what are called *magnetic storms*. Earthquakes and volcanic eruptions have a marked effect on the needle. The Aurora Borealis is invariably accompanied by its disturbance; and the appearance of solar spots, which are most numerous every ten years, has been associated with special magnetic irregularities.

Inclination or Dip.—If an unmagnetised needle be balanced about an axis, so as to remain horizontal, it will, after being magnetised, and placed in the magnetic meridian, no longer lie evenly, but will *point downwards*. This *dip* or *inclination*, as it is termed, of the needle to the horizontal is owing to the position of the earth's magnetic poles. They are deep in the interior of the globe, and by no means coincide with the poles of its axis. Now, if we take a small balanced needle, which can swing vertically up and down, and move it over a bar-magnet, we find that when it is above the middle of the bar, it remains horizontal, its ends being equally attracted by the poles of the magnet. When brought over one of the poles, it stands upright, and at any position between, it is more or less in an inclined direction. Exactly similar to the action of the bar-magnet is that of the earth. A balanced needle will be differently inclined, according to its distance from the two poles.

Over the north magnetic pole, it stands upright, with its north pole down. In 1831, Captain Ross came upon a spot in 70° 5′ N. lat. and 263° 14′ E. long. where the needle stood vertical. That spot must therefore be right over the north magnetic pole. Near the equator, again, there is no dip, and the needle lies horizontal. A line drawn through all such places of no dip is called the *magnetic equator*. It is an irregular line near to, but not identical with the earth's equator. Charts have been drawn up with lines shewing all places where the dip is the same. To these the name of *isoclinic lines* and *charts* is given.

Like the declination, the dip is subject to *periodical* as well as *irregular* variations. At the beginning of the present century, the dip was 70° 35′ from the horizontal in London, and it has since then been gradually diminishing. In London, it is at the present time about 67° 50′, and there is an annual decrease of about 2·6′. It is found that the diurnal or daily variations, as well as the disturbances of magnetic storms, affect the inclination at the same time as they affect the declination needle.

Magnetic Intensity.—If a nicely poised needle be made to swing on a pivot or axis near a magnet, it will vibrate more quickly, or more slowly, according to the strength of the magnet, and according to its distance from it. At the middle of the magnet, it will not vibrate so actively as at the ends; and the number of vibrations it will make in any time, say in one minute, will be an estimate of the *magnetic force* affecting it. Precisely in this way, then, is the strength or intensity of the earth's magnetism found at any place on its surface. At the equator, the needle, oscillating most slowly, shews the magnetic intensity to be weakest there. As we go north or south, it swings somewhat more quickly, indicating an increase of magnetic force.

These three indications, then, of the *declination*, as shewn by the compass needle, of the *inclination*, as shewn by the dipping needle, and of the *magnetic intensity*, as shewn by the vibrating needle, are termed the *magnetic elements* of a place. They are different at each place on the earth, and are always changing, so that each spot has its own magnetic history.

In recent years, much importance has been attached to these changes of the magnetic elements. An immense amount of labour has been spent in observing and registering the variations of the magnetism at different stations over the globe, but much more will doubtless have to be done before any definite results can be expected.

The variations that have been found to be regular in their occurrence, having periods either of a year, or of a month, or of a day, can evidently be traced to the influence of the sun or of the moon. These bodies are themselves, in all probability, magnetic like our earth, and they will act as huge magnets at a distance.

Some of the irregular variations can be traced, as we have said, to definite causes. But of the slow changes which take centuries to effect, no acceptable explanation has yet been given; and of the causes of other disturbances we know as yet absolutely nothing.

ELECTRICITY.

Six centuries before the Christian era, it was known to the Greeks that *amber*, when rubbed, attracted light objects, such as feathers or pieces of straw; but for twenty centuries, the fact remained an isolated and fruitless one. In the year 1600, Dr Gilbert, physician to Queen Elizabeth, recalled this curiosity of nature to the attention of the world, and shewed that many other substances, as well as amber, can acquire a similar power by friction. This attraction he ascribed to the production in the bodies of a subtle substance, for which he coined the name of *electricity*, from the Greek word *electron*, meaning *amber*.

For almost two hundred years, the term electricity was confined to the *frictional excitement*, until, by the discovery of galvanism, it received a wider application. This was but the first of a series of subsequent extensions, and what was, at one time, the whole, forms now but a mere part of the science of electricity.

The various sources of the electrical excitement, such as friction, chemical action, magnetism, and heat, naturally form the bases for the divisions of the subject. We shall accordingly begin with an account of the electricity of friction, which, if not of most practical importance, is no less interesting in itself than it is instructive.

FRICTIONAL ELECTRICITY.

Elementary Facts.—A piece of amber, sulphur, glass, or sealing-wax, when rubbed with a dry silk handkerchief, or a woollen cloth, becomes animated with a curious power of attracting small bits of paper, hairs, feathers, and such-like. When

a body manifests this attractive power, it is said to be in an *electrical state*, or to be *electrified;* and the name *electricity* is given to the strange physical cause of the power, which the rubbing has called into existence.

For experiments in this subject, it is useful to have a number of small pith-balls, formed from the pith of the elder-tree, or of the common sunflower. One of these, hung by a *silk* thread from a convenient support, is called an *electric pendulum*, and shews very readily the attraction of an electrified body.

But every substance which we rub as we did the glass or sealing-wax, will not behave in this manner. A rod of metal, held in the hand, will shew no trace of electricity, though it be rubbed ever so long. It is clear, therefore, that all bodies are not alike with regard to the electrical state.

The difference used to be explained by saying that amber, glass, and such substances are *electrics*, while the metals and others are *non-electrics*—that is to say, that the former class can be electrified by friction, while the latter cannot. This idea is now known to be erroneous. For, if the metal be held by a glass handle, and rubbed, it will at once shew its attractive power.

The true explanation lies here. In some substances, the electrical state is no sooner produced at any part than it instantly diffuses itself over the whole. In others, it is confined to the part where it is produced, or, at least, spreads over the rest of the body very slowly, and with great difficulty. According as bodies admit this instant diffusion or transmission of the electrical state or not, they are now termed *conductors* or *non-conductors*. *Non-conductors*, such as dry air, glass, shellac, &c. are also called *insulators*, because, if an electrified body is surrounded by such, its electricity is inclosed as in an island, and prevented from escaping over other conductors. The earth is a huge conductor, and any electricity, which we can artificially excite, must be carefully insulated from it, otherwise, if allowed to spread over the earth, it will be lost in its immensity, like a wave on a boundless sea.

We can now easily understand the difference between rubbing a rod of metal and one of glass held in the hand. In the former case, the electricity is dissipated as fast as it is produced, while the glass acts as the insulator of its own electricity.

There is no such thing as a perfect conductor or a perfect insulator. In other words, the very best conductors offer *some* resistance to the diffusion of electricity, and the very worst do not wholly prevent it. Nor is there any sharp line between the two; the difference is merely one of degree, and depends on a variety of causes. Temperature, for example, has a marked effect on conducting power. Thus, water is a moderate conductor, yet ice and dry steam are both insulators.

The following is a list of bodies in order, from the best conductors to the best insulators: *Silver, copper, gold, zinc, iron, lead, mercury, charcoal, acids, salt solutions, rarefied air, pure water, stone, dry ice, dry wood, porcelain, dry paper, wool, silk, glass, sealing-wax, sulphur, resin, gutta-percha, india-rubber, shellac, paraffin, ebonite, dry air*, and *gases*.

Looking more closely at the action of the rubbed glass rod on the electric pendulum, we see that the attraction is merely momentary, and is followed by as brisk repulsion. Any attempt to bring the rod near to the pith, only serves to drive it farther away. But if an excited stick of sealing-wax be brought near, the pith instantly flies to its embrace, only, however, to be in a moment cast off, as it had been by the glass before. Banished from the wax, it will now find favour with the glass for an instant again; and thus a continual exchange of sympathy for the one or the other electrified body may be kept up as long as the excitement continues.

Now, this curious behaviour of the pith can be accounted for only on the supposition that there are two opposite states of the electrical excitement, one peculiar to the glass, and the other to the sealing-wax. What the one repels, the other attracts, and the characters of the electricities must therefore be as opposite as are attraction and repulsion.

In any case, the excitement is either like that of glass or that of sealing-wax; thus, any electricity used to be defined as either *vitreous* or *resinous*. But these terms are not quite correct, as either kind may be got from the glass or from the wax, by varying the nature of the rubber. For *vitreous* and *resinous*, the terms *positive* and *negative* are now used—positive electricity being like that evoked on glass by rubbing with silk; and negative, that evoked on sealing-wax by rubbing with flannel.

Laws of Electricity.—The laws of frictional electricity are strikingly like those of magnetism. Often both may be expressed in the same language.

(1.) As with magnetism, so with electricity. *Like kinds repel: unlike, attract each other.* If we take two piths hanging together by two silk strings, and bring near a rod of glass or of sealing-wax, they will repel each other, and remain apart. But if we electrify one with the glass, and the other with the wax, they will attract.

We can thus at once tell the nature of any electricity by its repelling a pith electrified by glass or by sealing-wax. Mere attraction is no test, as a neutral body is attracted.

(2.) But as we never have one pole of a magnet without its fellow, so both kinds of electricity are always produced at the same time, and in equal amount. One kind goes to the body rubbed, and the other to the rubber. Faraday, whose name is so closely associated with this subject, shewed this fact by a very simple experiment. He made a small flannel cap to fit the end of a stout stick of sealing-wax. After rubbing the cap round the end of the wax, and presenting it to a pendulum, not the slightest effect was seen before removing the cap. But on drawing it off, by a silk string attached to it, he found the end of the rod negatively, and the cap positively, electrical.

The kind of electricity that goes to each depends on the nature of the rubbing bodies. Thus, if we rub glass with silk, the glass becomes positive, but if we rub it with cat-skin, it becomes negative. It is a curious fact that no body has yet been found which will give positive electricity when rubbed with a cat-skin.

If any two substances in the following list be rubbed together, that one which comes first in the list will be positive: Cat-skin, flannel, glass, cotton, silk, the hand, shellac, metals, sulphur, india-rubber, gutta-percha.

(3.) The electrical excitement is only found on the *surface of a conductor*. This may be shewn by a hollow brass ball with an opening of an inch diameter or so, and fixed on a glass stand. However strongly we electrify the ball, not the slightest trace of electricity will be found inside. Faraday took a cylinder of wire-gauze, and, setting it on an insulating stand, electrified it powerfully. Yet, strange as it may seem, none could pass by the meshes to the inside.

Electrical Theories.—Many theories as to the nature of electricity have been proposed, but its real character is yet beyond our reach. The two most historically important theories are the *fluid theories* of Franklin and of Symmers.

Franklin's theory is, that all bodies, when in the neutral state, contain a definite quantity of an extremely elastic, imponderable fluid which repels itself, but attracts matter. Bodies are positively electrified when they have more than their natural share of it, and negatively when they have less. Symmers' theory is, that bodies in the neutral state contain equal amounts of *two* electrical fluids, of opposite characters. By friction and other means, these can be separated, one going to each body rubbed. Each repels itself, but attracts the other, and one is peculiar to rubbed glass, and the other to rubbed sealing-wax.

These fluid theories were long exclusively adopted, and on them are based all the leading terms of the science.

The modern tendency, however, is to depart from all *material* theories of electricity, and to adopt some one more or less analogous to those of heat and light. They are based on the fact, that heat may be transformed into light and electricity, and also that electricity may be converted into light and heat. Light and heat are now ascribed to vibrations of an extremely elastic *ether*, which is so rare or fine as to pervade the densest matter as easily as air does the branches of a tree. So electricity is ascribed to some other modification of this ether, such as condensation or rarefaction of it at the surface of bodies, there being evidently some mutual influence between matter and the ethereal medium.

One thing is certain—electricity is not known to exist apart from matter, and it is very probable that it is but some particular *state* of the particles of matter. Faraday and Grove ascribed all electrical phenomena to a polarisation of the molecules of bodies, acting by attraction or repulsion, according to very definite laws. Faraday, by a series of testing experiments, went far to establish this theory, which would overturn all the fluid theories.

Induction.—An electrified body has the power of inducing, or of affecting a neutral one in much the same way as a magnet does a piece of soft iron. This may be shewn very simply in the following way. A brass cylinder with rounded ends, and fixed on a glass support, has pairs of piths hung at each end (fig. 7). If, now, an insulated conductor, such as a brass ball, be charged positively, and brought *near* one end of the cylinder, *both* pairs of piths will instantly diverge, and as quickly collapse when it is taken away. It is easily shewn that the two ends of the cylinder are in opposite electrical states, and separated by a neutral line of no electricity. Next the positive ball there is negative electricity induced, and so it is always. A charged body induces an opposite kind of electricity on the side of another next it, and the same kind on the farther side. If we had a series of cylinders like that in the figure, placed end to end in a line, without contact, we should find that the positive end of the first cylinder would act on the next just as the ball did on itself. Thus the induction might be transmitted through the whole of them; and, on our removing the inducing ball, they would all return to the neutral state instantly.

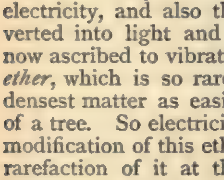


Fig. 7.

Opposite forces are here, as in a magnet, resident in opposite sides of the conductors. They are therefore said to be *polarised*, and the facts of electric induction are all in accordance with the laws of polarity. Indeed, there seems every reason to infer that all electric action is of a polar nature. When a rubbed glass attracts a pith, it is an attraction between the positive of the glass and the negative it has induced on the face of the pith next it. This is quite analogous to the action of a magnet on a piece of soft iron. There is, however, an apparent contradiction of this polar doctrine, for we may give to a body by induction only *one* kind of electricity, and this it retains permanently. If, while the cylinder is near the positively charged ball, we touch it for a moment with the finger, we uninsulate it, and allow its electricity to spread over the earth and become lost. Only the positive, however, will escape; the negative will be held *bound* to the positive inducing charge. If *after* thus touching the cylinder, we remove the ball, we shall have remaining on the cylinder *only negative* electricity. This is very different from what we can do with magnetism. There seems here no second electric polarity.

The explanation, however, is not far to seek. All matter can be excited electrically, but only one kind magnetically. In the case of electric polarity, then, it is possible to transfer one of the poles by induction to surrounding objects, whereas, in magnetism, this transference cannot take place. Not only is it possible, but it is what must take place before we can have any electricity at all. Faraday has shewn that a body cannot be electrified at all, either positively or negatively, unless there be surrounding objects to which it can transfer the opposite electricity by induction, and that the degree of charge which it can take is just in proportion to this facility for induction.

When a body is charged by induction, then, we see its electricity is opposite to that of the charging body. But when we charge it by contact or by spark, the electricity is of the same name as that of the charging body. Yet the latter is due to induction as well as the former. For when we bring the ball (fig. 7) near the cylinder, the positive electricity of the ball tends to unite with the negative it induces next it. The tendency increases as they approach, till at last it is sufficient to burst through the interval of air; and the two flash together with a spark, and neutralise each other. Thus, the positive electricity at the other end of the cylinder is left alone without its negative, just as if the positive of the ball had passed or flowed over to it.

Faraday shewed that the air is the medium by which the electric force passes between an inducing and an induced body. He found that, if he changed this medium and put shellac for air, the amount of electricity induced was about twice as much as with air. Hence he called shellac a better *dielectric*, or medium of induction, than air. Bodies, he would say, differ merely in the facility with which their molecules communicate the electric state. If induction, then, be an action at a distance, it is at no greater distance than between the molecules of bodies.

Distribution of Electricity.—Whatever may be the nature of electric force, it may be assumed as self-evident that its intensity, or tension at any part of the surface of a body, will be less in proportion as the surface is increased. If two insulated balls, one electrified and the other neutral, be made to touch, the charge will be just divided between them in proportion to their size. The intensity of the excitement has nothing to do with its quantity; and the same quantity may, in different circumstances, possess very different intensities.

Not only does the size, but even the *shape* of a body very materially influence the intensity of the excitement at different parts of its surface. A ball, since every part is alike, will have the same intensity all over its surface. But an electrified cylinder will have the greatest intensities at its ends. With a body such as that in fig. 8, the tension will be far greater at the ends than at the middle. In general, the farther a body is from the spherical shape, the farther will its intensity be from uniform distribution. When the body ends with a sharp point, the electricity seems all to accumulate at the point, so that it is too great to be retained on the body, and it bursts from it instantly.

Fig. 8.

ELECTRIC MACHINES.

The ultimate object of all electrical machines is the conversion of mechanical into electrical force. We have, in the glass tube and silk rubber, the embryo of such a contrivance. The mere form which may be given to it for convenience does not affect the principle.

Cylinder Machine.—Fig. 9 represents one of this class of machines in its very simplest form. It consists of a strong glass cylinder, A, which can be turned by a handle. Against one side of it presses the rubber, E, which is a cushion of leather stuffed with horse-hair, and having its pressure regulated by means of screws. Facing the opposite side is a row of brass points, near to, yet not touching the glass. These metal points communicate with a brass cylinder, G (rounded at the ends, and mounted on well insulating glass supports), which is called the *prime conductor.*

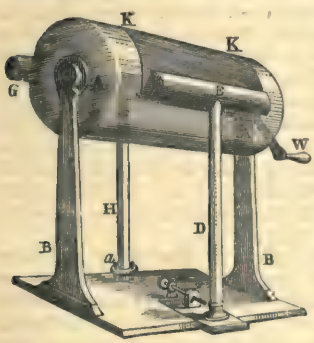


Fig. 9.

When the handle is turned, the friction of the rubber excites positive electricity on the glass, and negative on the rubber itself. Being a non-conductor, the glass retains its electricity till brought opposite the points, when it is discharged or picked up, as it were, by the action of these. Were a metal cylinder used in place of a glass, the electricities would combine at the rubber as fast as they were produced, and the mechanical energy exerted in turning the cylinder would appear as *heat*, instead of being transformed into electricity. To prevent dissipation of the electricity from the glass as it rushes through the air, a flap of silk lies over the cylinder from the rubber to near the metal points. In this way, then, positive electricity collects on the prime conductor, and negative on the rubber. If the latter were insulated as well as the former, the tendency of the electricities to unite at the rubber would increase with its charge, and a limit to the power of friction to prevent this would very soon be reached. By connecting the rubber with the ground, we get rid of the negative electricity, and can thus go on accumulating to a much greater degree the positive. In many instruments, the rubber is connected with an insulated cylinder similar to that of the prime conductor. Positive or negative electricity may then be had at pleasure, by connecting with a metal rod or chain either the rubber or the prime conductor with the ground. But except for this choice which it puts in our power, it is not necessary to insulate the rubber at all.

Plate Machine.—One of the best existing forms of plate machines is that shewn in the figure, and known as Winter's machine (fig. 10). A round

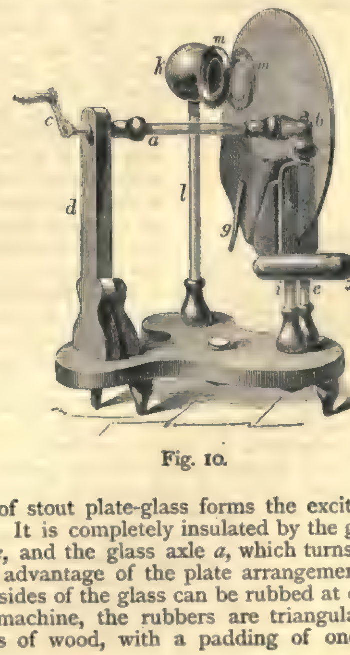


Fig. 10.

disc of stout plate-glass forms the excitable surface. It is completely insulated by the glass support *e*, and the glass axle *a*, which turns it. The chief advantage of the plate arrangement is that both sides of the glass can be rubbed at once. In this machine, the rubbers are triangular-shaped pieces of wood, with a padding of one or two

layers of flannel covered with leather; and a large flat rubbing surface thus acts on the glass.

From these rubbers a flap of oiled silk passes on each side of the plate to near the collecting points, to prevent loss of electricity. The attraction of the rubbed plate keeps these flaps in position when the machine is in action; at other times a split pin, *g*, is used to keep them up.

A peculiar feature in Winter's plate machine is a large ring which fits into the ball of the prime conductor. It is apparently a wooden ring, but the core consists of a metallic wire, which communicates with the prime conductor, when it is fitted in its place. The figure (fig. 11) shews a section of the ball of the prime conductor with the ring so fitted on. It serves to increase the accumulation of electricity enormously; the wooden envelope appears to prevent the discharge into the air, as the silk flap does with the electricity of the plate.

Fig. 11.

But we must not omit to notice that the frictional excitation of electricity is, in all these machines, very greatly enhanced by covering the surface of the rubber with an *amalgam*, or metallic compound. It is in the shape of a fine powder, and is usually made of mercury, zinc, and tin; it is spread on with a knife, and made to adhere by the aid of a little grease.

The Electrophorus.—This is the least expensive of all electric machines, and forms a useful piece of apparatus when we do not require electricity in great quantity.

It usually consists of a tin mould filled with shellac, and a movable tin cover with an insulating glass handle, as seen in fig. 12. The shellac is generally mixed with wax, to make it less brittle; but any resinous cake will do, if it be even and smooth on the surface. A round disc of vulcanite forms an excellent substitute for the shellac.

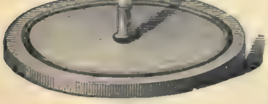


Fig. 12.

The principle of action of the electrophorus depends on induction, and is easily understood. If the cake be excited, say negatively, by striking with a cat-skin, it will not give up its electricity readily, because it is a bad conductor. Now, this negative electricity will induce positive on the adjacent sides of all objects round the cake. But as shellac is a splendid dielectric or medium of induction, the power will almost all act through it, and so keep positive electricity *bound* on the face of the mould next the cake, the negative being diffused over the earth. If, now, we put on the cover, the electricity, loath to leave the cake, will act on it by *induction*, rather than pass to it by *conduction*, and by induction powerfully, because the cover is so near. So, then, if we touch the cover for an instant, the negative induced on its upper side escapes; but the positive is kept *bound* by the cake, till we lift the lid by its handle, when a sharp spark passes to the knuckle held near it. By putting on the cover, touching, and then lifting it, we may get any number of sparks from the cake. Once excited, it will keep its power for a long time, sometimes for weeks or even months together. The mould shields it by induction, as the armature of a magnet does its magnetic charge.

Within the last few years, some machines have been invented by Holtz of Berlin and Tœpler of Riga, which have become very popular. They are generally called *double induction machines*, and are founded on a principle somewhat analogous to that of the electrophorus. A description of them will be found in any of the recent larger treatises on electricity.

Experiments with the Electric Machine.—(1.) The phenomena of *electric attraction* and *repulsion* may be illustrated in hundreds of ways. If a common glass tumbler be electrified inside, by a number of sparks from the machine, and then inverted over a few piths on a table, the piths will dance up and down within the tumbler in an amusing manner. They are gradually discharging the electricity of the tumbler, and the dance may be kept up for hours. Small pith figures will dance between two metal plates, the lower of which is uninsulated, and the upper in connection with the prime conductor.

The repulsion of similarly electrified particles is shewn very nicely by the *electric water-pail.* This is simply a small tin pail with fine holes pierced in the bottom. If filled with water, it will, when held in the hand, trickle out in drops merely; but if hung on the prime conductor, the water particles becoming electrified mutually repel, and issue in a multitude of fine jets. The *electric wind* is a somewhat similar result of the electrification of the particles of the air. If a pointed rod be stuck in the prime conductor, and the machine worked, the hand placed before the point will feel a sort of wind. The experiment may be made pleasing to the eye, by making the wind drive small models of mills or a small paper orrery.

This action of points is very curious. So long as the electricity escapes from the prime conductor by a point, no spark can be drawn from it. Nor, on the other hand, can any spark be got, if a pointed conductor be held at a distance of a few feet from the machine. This is because the electricity escapes silently in each case, and cannot acquire a tension sufficient to give the spark. The snap, heard when a spark is drawn, is due to the disruption or scattering of the air particles, caused when the positive electricity of the machine combines with the negative it induces on the hand or the object brought near it.

(2.) The *heating effects* of electricity are also very powerful. If a spark be drawn from the prime conductor by an iron spoon containing a little ether or alcohol, the liquid will instantly inflame. It will also light a candle newly blown out. A gas-jet issuing from a metal burner is instantly lighted by a spark from the machine, or from the finger of a person standing on a stool with glass legs and touching the prime conductor.

(3.) The *luminous effects* of electricity are, of course, most visible in the dark. The light of the spark is intense when the machine is powerful and in good order. When short, it seems straight, but it gets more and more irregular and zigzag the longer it is. If the ball of a Winter's machine be allowed to discharge into the air, the spark will be seen to spread out into the form of a *brush*. But if it be made to discharge silently from a point, the point will be seen, in the dark, crowned with a tuft of light, which is usually called the *glow*. The glow is more readily got, and becomes much more extended in rarefied air. A tall glass jar, from which the air can be pumped out, is used to shew this. It has a brass ball at each end, and the electric spark passes between these by putting one end in connection with the machine, and the other with the ground. The glow throughout the jar has the appearance of a column of mauve-coloured flame. But the colour of the luminous discharge varies with the nature of the metals between which it passes, and also with the nature of the gaseous medium. The flickering light thus produced has a striking resemblance to the Aurora Borealis.

ELECTROSCOPES AND ÉLECTROMETERS.

Instruments for *detecting* the presence of feeble electricity are called *electroscopes;* and those for *measuring* the degree of excitement present in any body are termed *electrometers.* Both are indispensable in electrical inquiries.

The simplest form of electroscope is the electric pendulum already mentioned.

Far more delicate, however, is what is known as the *gold-leaf electroscope.* A good form of this is shewn in fig. 13. Two strips of gold-leaf about half an inch broad are fixed to a brass rod so as to hang inside a glass globe of about four inches diameter. The brass rod ends externally in a ball, and is insulated with sealing-wax from the brass fitting of the neck. Before the rod and leaves are finally fixed, the interior of the globe is thoroughly dried, that the insulation of the leaves may be as perfect as possible. When so finished, this forms a very sensitive instrument: an extremely small amount of electricity being sufficient to make the leaves diverge. A strong charge would be very apt to tear the gold-leaves, and it must therefore be used with care.

Fig. 13.

When we simply wish to test the kind of electricity on a body, induction is generally employed, and in this way. The electrified body under examination is brought near the electroscope, and the knob of the instrument touched in presence of the body. By withdrawing the electrified body, we leave the leaves charged oppositely to itself, and so they diverge. To find if they are positively or negatively charged, we rub a glass rod and bring it *near* the knob: if *positively*, the leaves will diverge still more under the induction of the glass; but if *negatively*, they will collapse by the negative being attracted to the positive of the glass rod.

Of electrometers, one of the first and simplest is that shewn in fig. 14, and called the *quadrant pith electrometer.* It consists of a conducting-rod of brass or of box-wood, with a divided semicircle of cardboard attached. A straw ending in a pith-ball moves about a pivot at the centre of the semicircle, and indicates, by the extent of divergence from the brass rod, the degree of electrification of the instrument. It is very far from delicate, however, and gives but a rough test of electric tension. Its chief use is to put on the prime conductor of a machine, to give an idea of its condition.

Fig. 14.

A much more delicate instrument of this class, and one which has had a considerable effect in rendering electricity an accurate science, is *Coulomb's torsion electrometer.* It is represented in the figure, and merits a short description here (fig. 15). A light rod of shellac, carrying a small disc of gilt paper at one end, is suspended by a silk fibre, or fine silver wire, within a glass cylinder A, and a glass tube, B, surmounting it. The cylinder is divided into degrees by a graduated strip of paper pasted round it; and the position of the gilt disc is known by reference to this graduation. Through an opening in the lid of the cylinder, a brass ball, at the end of a shellac rod, can be passed so as to be supported on a level with the gilt disc.

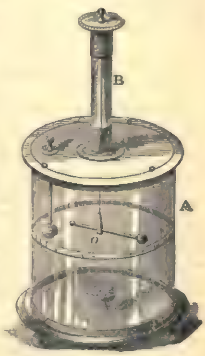


Fig. 15.

Before using the instrument, we must adjust it so that, when the fibre hangs free from twist, the gilt disc just touches the ball. If this ball be electrified, it electrifies, and then repels the disc, to a distance depending on the strength of charge in the ball. Now, the principle on which its use depends is that—*the force required to keep a fine wire or fibre twisted through any number of turns and parts of a turn, is just proportional to that number of turns and parts of a turn.* By turning the button, to which the fibre is fixed at the top of the tube, we can bring the disc to any distance from the ball that we please, say to 30°, as read off on the cylinder. Then the number of turns and parts of a turn (read off by reference to a graduated ring on the top of the *tube*), added to the 30° between the ball and the disc, gives the whole amount of twist of the fibre from the first position of no twist. This force of twist is just balanced by the repulsion of the electricities in the ball and disc, and is therefore a measure of that repulsion. By a great number of such experiments, Coulomb established the following laws of electrical attraction and repulsion:

(1.) The force of attraction or repulsion between unlike or like electricities *decreases* as the distance between them increases, and decreases as the *square* of the rate of increase of the distance. Thus, the force of repulsion between two similarly electrified piths, 1 inch apart, would be reduced

to ¼ of that at 2 inches', and to ⅑ at 3 inches' distance.

(2.) This force depends also on the *product of the intensities* of the electricities that are acting on each other. So that, if one ball had its electricity raised to three times its first amount, and another to twice, the resulting action between them would be six times as strong as at first.

The construction of delicate electrometers has of late years occupied the attention of our greatest authorities on this subject. Their aim has been to render electricity a strictly accurate and mathematical science; and the labours of Sir William Thomson and others have done more to effect this than any have ever done before. Sir W. Thomson has himself invented several forms of electrometers from time to time, each more accurate than the former; and his *Absolute Electrometer* and his *Quadrant Electrometer* seem as perfect as is reasonably to be expected. The latter is out of sight the most delicate instrument of the kind. A description of these is beyond the scope of this article, but may be found in the various works on electrical science or apparatus.

CONDENSED ELECTRICITY.

There is a limit to the accumulation of electricity on any surface. After it has reached a certain degree of intensity or tension, it discharges into the air as fast as it is produced. But if we bring another conducting surface *near to* the charged one, the latter may be much more highly electrified than before. This is the principle on which the *Leyden jar* depends, and a description of it will serve to explain the nature of condensed electricity.

The *Leyden jar* is simply a wide-mouthed glass bottle with two coatings of tinfoil, pasted one outside, and the other inside (fig. 16). The coatings reach only about four-fifths of the height of the jar, and the bottom is also covered inside and outside. A brass rod ending in a knob passes through a wooden plug in the mouth of the jar, and communicates with the inside coating by a piece of chain. If, now, we set such a jar on an insulated support, so that sparks can pass from the prime conductor of a machine to its knob, a few sparks will pass, and then it seems charged, and will take no more. But if we hold a knuckle near the *outer* coating, sparks will again pass freely to the knob; and for every spark to the knob, a similar one passes to the knuckle from the outer coating.

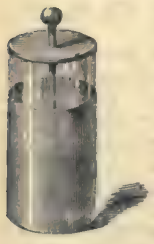


Fig. 16.

This continues for some time, till again the jar becomes fully charged or saturated. So long as it remains on the insulated support, we may touch *either* the outside coating *or* the knob. But if one hand touch the outside, and the other be brought near the knob, a bright spark passes to it, and a very violent shock is experienced. If the same thing be done again, a feebler spark and shock ensue, and then the jar is quite discharged. This experiment had better be made, however, with a pair of discharging tongs (fig. 17), as it is neither pleasant nor safe to do it with the body. They are simply two brass arms ending in balls, and movable about a hinge by means of glass handles. One ball is made to touch the outer coating, while the other is brought near the knob. The usual way of charging the jar is to hold it in the hand, and present its knob to the prime conductor of a machine.

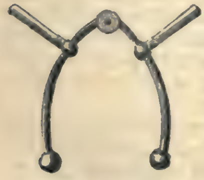


Fig. 17.

Its theoretical explanation is just a case of the general principle, that the charge which a body can receive is greater in proportion to its facility for induction. Now, when the inner coating is positively charged from the machine, it acts by induction on all neighbouring matter, and the nearer and larger this matter is, the greater will be the charge it can take. If, then, the jar be uninsulated, we have really the surface of the earth brought within the thickness of the glass from the inside coating. The glass, too, which intervenes is a very good dielectric, much better than air; at the same time its tenacity can resist the strain of a far higher polarisation of its particles than air would do. Thus we have every facility for a high charge of the interior. It would, of course, be greater, the thinner the glass; but thin glass is easily ruptured, and would be of no use. If we could have a jar of indefinite thinness, and yet of great strength, the charge which it could take would be unlimited. As this is not the case, other bodies round about compete, for induction, with the outer coating. Ultimately, the facility of induction through the air on these becomes greater, and there is an end of the charge.

If the inside is positively charged, the outer coating is negatively next it, and the two are bound together by the action of the glass, which is such a good dielectric. The glass also seems to be the chief seat of the charge, and the coatings seem to serve merely to distribute it over the non-conducting glass. This is usually illustrated by having a jar with movable coatings. After it is charged, we may remove each coating, handle them, put them back in their place, and get almost as strong a discharge as ever. The *secondary* discharge, which is got by connecting the coatings after the first discharge, is ascribed to the same cause. The glass does not give up all its charge at once, and sometimes three or four subsequent discharges may be got.

For great power, large surfaces are necessary. A large jar would give this, but it is preferable to use several moderate-sized ones, and unite them to form what is called an electric battery. The jars are placed on an insulated stool covered with tinfoil, and their outer coatings are thus in communication. All the knobs are connected by metal rods, and so all the inner coatings act as one. If, after charging, we connect any knob with an outer coating, the whole battery will be discharged, and with a force which, for the same degree of charge in a single jar, will be proportional to the number of jars employed.

The effects of condensed electricity are very powerful. If the spark be passed through a bad conductor, such as shellac, resin, or glass, it may be shivered into powder. A fine wire of metal will be made red-hot, or even melted, by the discharge of a good battery. The physiological

effects also are tremendous. A single jar, of moderate size, is sufficient to give a shock to a whole regiment. The men have simply to join hands and form a ring, the first man holding a jar, and the last man touching its knob. All will feel the shock at the same instant, so rapid is the rate of discharge. Indeed, the velocity of electricity, or of electric discharge, is almost incredible. Wheatstone, by a very ingenious method, has calculated that it can be no less than 288,000 miles a second—that is, it might flash round our earth in one-tenth of a second. More recent experiments and calculations, however, bring the velocity much nearer to that of light, which is about 190,000 miles a second.

ATMOSPHERIC ELECTRICITY.

Lightning.—Franklin was the first to identify the lightning flash with the electric spark. By his famous kite experiment, he found that the thunder-cloud acts just like the charged conductor of an electric machine. The same disruptive, burning, and luminous effects are common to both, though in vastly different degrees. There are several kinds of flashes. First, there is the zigzag flash, or *forked-lightning*, which appears as a broken line of light, bright, thin, and sharp at the edges. It may pass between clouds, or it may dart from the clouds to the earth. Often it splits up into branches as it approaches the earth, and they may be sometimes several thousand feet apart. Its zigzag form is owing to the resistance of the air. Second, there is the large indefinite blaze of *sheet-lightning*. It seems to spread over a large space, and is not so intense as forked-lightning. It is ascribed to an electric discharge within the clouds themselves, which illuminates their mass for a moment. When it occurs at a great height or distance, no thunder is heard, and a vague flash passes across our field of view. Such is common in summer evenings. A third and less frequent form is that of *ball-lightning*, which is perhaps rather a meteor than an electric phenomenon. It is said to occur in this way. After a violent explosion of lightning, a ball is seen bounding like a bomb to the earth. When it reaches the ground, it either splits up at once and disappears, or it rebounds like an elastic ball before doing so. It may last as long as ten seconds, and is thus very different from the flash, which has been proved to last less than one ten-thousandth of a second. It is very dangerous, and readily sets fire to any building in its way.

Thunder.—The *snap* of the electric spark is heard on a grand scale in the thunder-clap, which accompanies the lightning. Whether it is due to the disruptive scattering of the air particles in the line of discharge, or to the rushing in of air to fill up the vacuum produced, is not quite clear. Nor can the prolonged rolling, the strange rising and falling of the peal, be properly accounted for. When the thunder is near, it is short and sharp, though the same report may have been heard as a long roll at a distance. The echoes sent between the clouds and the earth may account for this rising and falling to some extent, but not fully. Some assign the cause to the zigzag path of the flash, forming a series of centres of sound, not all in a line. The waves of sound may alternately swell into one roar, or meet and weaken each other. Thunder is not so loud as we are apt to fancy it. It has never been heard more than 14 miles from the flash. The cannonading at Waterloo was heard at Creil, in the north of France, about 115 miles from the field.

Lightning-conductors.—Electricity, like any other force, always takes the easiest route. We have seen that, if we hold a pointed rod of metal to the prime conductor of a machine, its electricity will be all drawn silently off to the ground, as fast as it is produced. In the same way, if we present a pointed rod near to a charged cloud, its electricity will pass silently and harmlessly to the earth. This is the principle of the lightning-conductor. It is a pointed rod of copper or galvanised iron, reaching from 8 to 30 feet above a building, and carried down to the earth, in which it is carefully buried. The part above the building is called the *rod*, and the rest the *conductor*. They must be very carefully constructed, otherwise their presence is the opposite of protective. It is led down two feet or so into the ground, and then turned away into a well or water, if possible, or else into a drain filled with charcoal for 12 or 16 feet. In large buildings, there are several rods all connected to one common conductor. In ships, there is one on each mast, leading to the metal of the keel. When properly made, they are, beyond all doubt, sufficient protection from the ravages of lightning.

Ordinary Electricity of the Atmosphere.—In all kinds of weather, clear as well as cloudy, the air is more or less electrified. With a clear sky, it is always *positive*, and more or less at different times during the day. It is most strongly electrical shortly after sunrise, and again shortly after sunset. It is least when the heat of the day is greatest, and also just before sunrise. These changes are explained by the effect of the sun's rays on the moisture present in the air. In cloudy weather, it is sometimes positively, sometimes negatively, electrical. Rain, snow, hail, &c. when caught on an electroscope, are found sometimes positive, and sometimes negative. The cause of this electricity of the air is not satisfactorily explained. Some ascribe it to evaporation and vegetation. Some ascribe it to induction by a permanent negative electricity, resident in the earth.

GALVANISM.

The discovery of galvanism was the beginning of a new era in the history of electrical science. No results of great practical value had followed the study of the electricity of friction. Its nature was so capricious. A constant tendency to escape made it difficult to excite, and yet more difficult to control; and it found a place merely in the laboratory of the philosopher, or among the curiosities of the drawing-room. But the revelation of another and an easier mode of producing the excitement soon drew the attention of the whole scientific world. This new field of investigation displayed an entirely novel class of phenomena; and the short period of half a century saw marvellous and unexpected results. Frictional electricity thus became of subordinate importance, while galvanism or voltaic electricity became of the highest practical interest.

Elementary Facts.—Galvani, an Italian professor of anatomy, discovered, about the year 1780, that the limbs of recently skinned frogs were convulsed, if near an electric machine, whenever he drew sparks from the prime conductor. Experimenting on this electric susceptibility of frogs, he accidentally noticed one day a similar convulsion from a totally different cause. This was when a copper hook, stuck through the spine of a frog, came in contact with a piece of iron which was touching the muscles of the leg. The same action, though less energetic, took place when he connected the nerves of the back with the muscles of the leg by a single metallic conductor. Galvani identified the effect with that produced by the electric machine; and, after a great number of experiments, he ultimately ascribed it to the flow of a vital electric fluid from the nerves to the muscles. One fluid he considered peculiar to the muscles, and the other to the nerves.

Volta, an Italian professor of natural philosophy, repeated these experiments, but came to a different conclusion. As the action was much more violent when *two* metallic conductors were used, he inferred that the mere *contact of the different metals* was the exciting cause of the electric flow. One of the metals assumed the positive, and the other the negative electricity, and the frog's limbs but served as a sensitive connector. Such was the voltaic view.

It was, however, a problem which of the explanations was the true one. Each theory had its advocates and supporting experiments, and each party its name for the new species of electricity. Thus came the origin of the two terms galvanism and voltaic electricity, which are now used indifferently. Volta's theory had perhaps most support at the time. Yet Galvani's is not without reason, and may be said to be re-established by modern experiments on animal electricity.

In support of his theory, Volta devised many ingenious experiments, and among others was a simple apparatus, which excited extraordinary interest in its day. It is called *Volta's pile*, and was invented by him to shew the effect of a combination of metallic contacts. It consists of a number of pairs of round discs of copper and zinc piled together, as shewn in fig. 18. The copper and zinc of each pair were soldered together, and the zincs all faced the same way in the pile. Moist discs of cloth were put between each pair, merely, as Volta held, to prevent direct contact between the pairs, and yet be a sufficient conductor. The pile is insulated, and, as afterwards modified, ends in a copper plate above and a zinc plate below. By this means, a powerful accumulation of positive electricity was found at the copper plate, and of negative at the zinc. When the two ends of the pile were connected by a wire, a strong and steady flow of electricity set in from the one side to the other. On the limbs of a frog, the effect was much more violent than that of a single pair of metallic conductors. So, then, argued Volta, the mere contact of the copper and the zinc produces opposite electricities in each. For the more he multiplied the contacts, the greater was the electrical power of the pile.

Fig. 18.

Volta's theory took little account of the moisture of the cloth, but its importance was not to be overlooked. It was observed that, after a time, the zinc plates got corroded by the action of the moisture; and, if the cloths were wetted with salt water, a stronger electric action resulted, as well as a faster corrosion of the zincs.

Suspicion fell on this very *corrosion* as the real active agent in the matter. The doctrine of Volta was challenged by several eminent philosophers; and a theory tracing voltaic electricity to chemical action was set up against it. By the genius and labours of such men as Davy, De la Rive, Becquerel, and Faraday, a vast array of evidence has been brought to bear in favour of the chemical theory. It has been shewn, on the one hand, that in the experiments which were given to *demonstrate* the contact theory, chemical action is really at work, and that, if it be prevented, no electricity appears. On the other hand, it is proved that chemical action, or the union of two substances having a *chemical affinity or attraction*, is always accompanied by the liberation of electricity.

To put such matters beyond dispute is extremely difficult. There are no theoretical reasons why mere contact of dissimilar metals should not give rise to a statical charge, or, in more modern language, to a difference of electric potential in the metals. Recent experiment seems to reassert that mere contact does actually produce electricity, and that Volta was perhaps not so far wrong after all.

General Idea of Galvanic Action.—It is in accordance with the chemical view, that we proceed to examine the conditions essential to the galvanic current. The elementary form of arrangement, seen in fig. 19, is called a *galvanic element or couple*, and will serve to explain the nature of the action. A plate of copper, C, and a plate of pure zinc, Z, are put into a vessel of water, mixed with a little sulphuric acid. So long as they do not touch, nothing is seen, and no chemical action goes on. But the moment they touch at any part, either within or out of the liquid, bubbles of gas are seen at the copper plate, and they continue to form till we separate them again. We have the same result if we connect the plates, not directly, but by wires fastened to the plates. All that is visible is the production of the gas bubbles. But a hidden and most curious electric action is going on along the

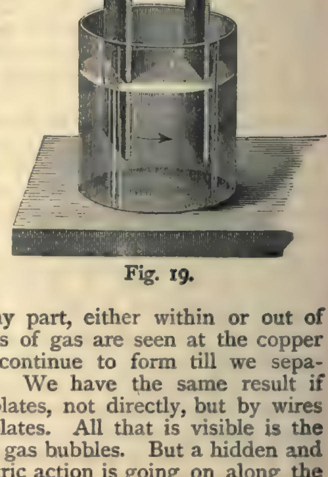


Fig. 19.

wire, and, indeed, through the whole arrangement. If we break the connecting wire, we may find, by the gold-leaf electroscope, that the end of the wire fixed to the copper is positively electrified, and the other wire negatively, though each in an extremely feeble degree. There the electricities remain shut up, and the chemical action suspended, till we bring the ends together. Then the opposite electricities combine and neutralise each other; and the whole, plates and wires, will be discharged or reduced to electric rest. But only for the instant; the action of the acid water sends a fresh supply of opposite electricities to each plate. So there is an incessant production and combination of the two electricities.

This constant succession of electric discharges is called a *current*, and it is said to *flow* in a *circuit* through the liquid, plates, and wire. If the circuit be *anywhere* broken, as by cutting the wire or lifting one plate out of the liquid, the *flow* of electricity instantly ceases. But the ends of the circuit, where the break is, become charged with opposite electricities; and the excitement is then said to pass from the *dynamic* or motive state to the *static*, or reposing state.

Theory of Action of a Galvanic Couple.—On collecting some of the gas, which is seen to form at the copper plate, we find it to be hydrogen. Why it should appear there, and not at the zinc, and why it should be formed at all, we shall now explain. When the plates of a galvanic pair are put in acidulated water, they are instantly thrown, by the action of the acid on the zinc, into opposite electrical states. The *zinc* becomes *positively*, and the *copper negatively*, polarised on the face next the liquid. But between the two plates, the liquid is also thrown into a polarised state. Water, as has long been known, is not a simple but a compound body, formed by the chemical union of oxygen and hydrogen. Each molecule of water may be looked on as an atom of oxygen bound to one of hydrogen, and these molecules are perfectly movable amongst each other, so that they can take up any position. Zinc and copper have each an affinity for oxygen, but zinc far more than the copper. When a plate of each is put into acid water, then we have this result along each line of molecules. The zinc plate turns the oxygen end of the first molecule to itself, and weakens its attraction for its hydrogen fellow. The latter turns its spare strength to attract the oxygen of the next molecule, and so on, till ultimately the positive hydrogen is presented to the copper, for which it has no liking, and induces on its face a negative polarity. In this way, then, we see the action of the acid water on the zinc, or the chemical affinity between the two, is a force urging all the particles of the liquid to set in a certain direction. In like manner, the chemical affinity of the copper for the oxygen tends to set the particles all in an opposite direction. The difference between these two forces constitutes what is called the *electro-motive force* of the couple. Had we taken a plate of silver with the plate of zinc, the resulting electro-motive force would have been still greater, because silver has less affinity for oxygen than copper has. But had we taken two plates of zinc, or two of copper, we should have been setting two equal forces against each other, and the electro-motive force would be *nil*. As a general rule, *the electro-motive force is greater the greater the difference of the metals in their liability to be acted on by the liquid.*

The face of the zinc, then, has positive, and the face of the copper negative, electricity; and all their molecules will be thrown into a polarised state, in accordance with our previous notions of electric action. By the doctrine of polarity, the further ends of each wire attached to the plates will have an opposite electricity to that on their faces. That is to say, the end of the wire from the copper will have positive, and the end of the wire from the zinc negative electricity. But the whole system, we are to remember, plates, wires, and liquid, is really in a polarised state.

When, now, we bring the ends of the two wires together, the positive electricity in the end of the copper wire tends to unite with the negative at the end of the zinc wire. Yet so feeble is the degree of polarity, or so weak is the *tension* of each electricity, that they are unable to unite unless there be absolute contact. When there is this, the two combine, and an instantaneous electric discharge is set up along the whole polarised course. The zinc can now unite with the oxygen atom next it; the hydrogen atom thus set free unites with the oxygen of the next molecule to re-form water; and so the hydrogen and oxygen atoms pair off, till next the face of the copper is left an unmatched atom of hydrogen. Having no affinity for copper, the hydrogen escapes in its natural form of gas. There is thus, with such a galvanic couple, an incessant union of oxygen with the zinc plate to form zinc oxide, and a setting free of hydrogen at the copper.

For the sake of simplicity, we have here supposed the liquid to be pure water. But this would only give a very feeble current, for the oxide of zinc, being a bad conductor, would stick to the surface of the plate and stop the action. A little sulphuric acid added to the water serves to dissolve this zinc oxide, and keep the surface of the plate clean and ready for action. Theoretically, the action is the same as before. The liquid may be regarded as formed of two atoms, one of hydrogen and one of *sulphion*, formed by the union of the sulphuric acid with the oxygen of the water. This sulphion atom behaves exactly as the oxygen did: it unites with the zinc to form sulphate of zinc, and hydrogen escapes at the copper plate.

Electro-chemical Order of the Elements.—We have just seen that zinc takes positive, and copper negative, electricity, when they form a galvanic pair, simply because zinc is the more oxidisable of the two. If we form a pair with copper and gold plates, we find the copper plate is now the positive one, and the gold the negative, because gold is even less oxidisable than copper. The plate which is more oxidisable, or more readily acted on by the liquid, always becomes positive, and is therefore said to be electro-positive to any less oxidisable metal. Knowing the relative degree of oxidability of any two metals, we can at once tell how they would act as a galvanic pair. The direction of the current is *defined* as being from the positive plate to the negative *within* the liquid, and from the negative to the positive *without*. Therefore, we have a general rule that, if we form a galvanic couple with any two metals and a dilute acid, the current will flow *outside* the liquid, or in the communicating wire, *from the metal which is least acted on by the acid to the other.*

In the following list, the more common elements are arranged in order of their oxidability, or in electro-chemical order: *Potassium, sodium, manganese, zinc, iron, lead, tin, bismuth, copper, silver, mercury, platinum, gold, hydrogen, carbon, phosphorus, chlorine, nitrogen, sulphur, oxygen.*

From this we know at once that a zinc-carbon pair will give a current flowing, *within* the liquid, *from zinc to carbon.* It follows, from what has been said, that the electro-motive power of any combination will be greater the farther apart they are in this list. For example, a zinc-platinum pair will be more powerful than a zinc-copper one.

But this is the electro-chemical order only for dilute acids as the exciting liquid. With other liquids, we may reverse the order of the polarity. In a solution of common salt, iron is positive to copper negative; while in ammonia, or hartshorn, iron is negative to copper positive. For dilute acids generally, however, the order is exactly the same, and such as we have given it above.

Galvanic Choice of Corrosion.—It is a curious fact, that if two metals be placed in contact, in a liquid which can act on both, only the one which is more oxidisable will be attacked. In the galvanic pair, the zinc only is eaten away, though the acid would act on the copper if no zinc were present. Hydrochloric acid (or spirit of salt) acts readily on iron, but much more readily on zinc. If, then, a piece of zinc and iron be put in the acid, and made to touch, the zinc will be all dissolved before the iron begin to be corroded.

Another illustration of the same fact is seen in the action of sulphuric acid on zinc itself. If the zinc of a galvanic pair be pure, the acid scarcely acts on it at all until the circuit is complete; but if it be impure, then, as soon as it enters the acid, there is a strong effervescence. The reason is, that the other metal particles, such as lead, carbon, iron, &c. present in the zinc form with it just so many closed galvanic circuits, and the zinc wastes rapidly away. This *local action,* as it is technically called, causes not only a useless waste of zinc, but also a serious enfeebling of the current. Pure zinc would be far too expensive to use for galvanic purposes; but happily it is found that *amalgamating* the plate, or rubbing some mercury over its surface, renders the ordinary commercial article as good as the pure zinc for the purpose.

Comparison of Voltaic and Frictional Electricity.—Although the electricity of galvanism is undoubtedly the same natural agency as that of the machine, there is a marked difference between the two, of which it is important to have a clear conception.

The difference is expressed by saying that, in the voltaic current, we have a large amount or *quantity* of *very feeble* electricity; while, in the electricity of friction, we have *great intensity or tension, but no great quantity.*

A very good illustration of the distinction between *intensity* or *tension* and *quantity* is furnished by the allied excitement of *heat.* The temperature of a body may be called its *heat-tension,* and has very little reference to the *absolute quantity* of heat-motion or excitement possessed by the body. A red-hot poker, for example, has heat of a very high tension, though the quantity is very much less than that of a warm-water bath.

Nor need we be surprised that the properties of voltaic and frictional electricity should differ so widely. The difference is not perhaps greater than that of the powers and properties which belong to heat of weak and of strong intensity. A small wire, made red hot, will suffice to burn the finger or explode gunpowder, though an infinite quantity of heat applied at low tension has no such effect.

In modern language, the electricity of the current is *kinetic* electric energy; that of the machine is *potential* electric energy. The former —or actual motive form of the force—is electric energy in the course of transformation into another form. It will appear wholly as *heat* in the circuit, if it be used to do no *work;* or it may appear partly as heat and partly as chemical or mechanical energy. The sum of the new forms of energy is always an exact equivalent of the primary energy of the current. The potential energy of frictional electricity is, like that of magnetism, power in store, ready to be transformed into *kinetic* energy, such as attraction, when suitable circumstances arise.

GALVANIC BATTERIES.

When a number of galvanic pairs, such as we have described, are put together, so that the currents given by each shall all unite and flow in the same direction, they form a galvanic battery. The copper plate of each cell (fig. 21) is connected, by a strip of copper, with the zinc of the next, so that we have a zinc plate left alone at one end, and a copper at the other. These are called the poles of the battery, and the circuit is completed by joining the poles with a wire or conductor. The group thus acts exactly as a compound galvanic couple, the copper plate being the positive pole, and the zinc the negative. In the *outside* parts of the circuit, the direction of the current is always *from the copper to the zinc,* and in the *inside* or *liquid parts, from the zinc through the liquid to the copper.* By thus joining several couples, the polarisation of the first copper is transmitted to the second zinc by the connecting wire, and serves to heighten the effect of liquid number two in polarising zinc and copper number two. Obviously, therefore, the electro-polarising force of each cell serves to increase that of the next; and the result is, that at the final pole C, the electro-motive force or power to set up polarity along the wire leading from it is very great. It is just as many times greater than that of a single cell as there are cells so linked together.

We must, however, carefully distinguish between the *electro-motive force* of a battery and the *strength of current which it transmits.* In certain circumstances, *one* of the cells will give as *strong a current* as a hundred joined together as a battery, though the electro-motive force of the former is a hundred times smaller. Thus, the strength of the *current* is not to be confounded with the strength of the *cell* or *battery.* The strength or electro-motive force of a battery (or cell) is estimated by the amount of *statical charge* in the ends of the wires, before the circuit is joined—that is to say, by the amount of attraction or repulsion they can produce. So measured, then, the *strength of a battery* may be defined as *its power to propagate electricity, or push forward the polarisation against*

resistance. Now, if this resistance be *small*, the single cell will transmit the polarity as easily as the battery. That is to say, with a short good conductor between the poles, a single cell will give as *strong a current*, and deflect the magnetic needle as much, as a hundred. The superior electro-motive force of the battery has, as it were, no opportunity of exhibiting its power. With a long and difficult conductor between the poles, it is not the same. Here the strength of the battery is seen. One cell may nearly or even utterly fail to establish a polarity throughout such a circuit; yet the battery will push the polarity on in the face of it, and give a strong current, while the cell gives little or none at all.

Requisites of a good Battery.—The objects to be attained in a battery are chiefly two: first, that the strength of the battery, and, therefore, the electro-motive power of each cell, should be as great as possible; and second, that the battery should be able to keep up steadily, and for a long time, its original strength. The first condition must be provided for by selecting metals widely apart in the electro-chemical list, and by avoiding *local action.* As to the second condition, it is not such an easy matter to secure a battery uniform in its action. Several causes operate to impair its strength in course of time. The acid gets weak, and must be strengthened from time to time. Another injurious influence is at work always when the plates are placed in *one* liquid, and face each other directly. This is a tendency of particles of the one plate to pass to the other, and so to reduce that difference in the surfaces which is essential to the action. In the copper-zinc couple, for example, the dissolved sulphate of zinc forms a deposit on the copper plate, while some of the copper also passes to the zinc; so that in course of time the two surfaces become almost alike, and the current almost nothing. This is a grievous fault, but, as we shall see, it can be prevented by placing a porous partition between the plates. It gets soaked with the liquid, and so allows communication to pass. Yet it is close enough to prevent the exchange of metallic particles.

Besides these, there is another very serious cause of weakening, which requires special provision. It is known as *polarisation of the plates.* In all batteries, where hydrogen is set free at the negative plate, there is a tendency of the hydrogen bubbles to adhere to the plate, and a rapid fall in strength of current is the result. The hydrogen not only forms a non-conducting layer over the surface of the plate, but, what is worse, gives rise to a *counter* or a *secondary current.* This hydrogen deposit is prevented by using *two* liquids in place of one. Both must be conducting, and the *unaffected* or *negative element* is immersed in a separate liquid, of such a nature that the liberated hydrogen can act chemically on it, and thus be absorbed as fast as it is formed.

Various Forms of Cells and Batteries.—(1.) *Cruikshank's Trough Battery* was the first improvement on Volta's pile, of which it is but another form. Pairs of copper and zinc plates, soldered together, are fixed in a wooden trough, coated with some insulating varnish. The cells are filled with dilute acid, and correspond exactly to Volta's cloth discs. The defects of assimilation and of polarisation of the plates, described above, combine to make this battery unsatisfactory.

(2.) *Wollaston's Battery* is shewn in fig. 20, and is an improvement on the last. The copper plate is bent up so as to face the zinc on each side.

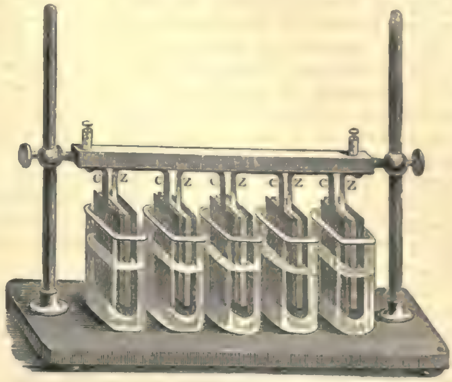


Fig. 20.

This clearly brings twice as much zinc surface into action, and so doubles the *quantity* of electricity which each cell will give. Each couple is immersed in a separate trough, to insure insulation. The zinc of one cell is connected to the copper of the next by a strip of copper soldered to each; and the whole may be raised out of the cells, when not in action, by means of the wooden rod supporting them.

(3.) *Smee's Battery* is, in general, similar to the former; only, in place of a copper, there is a thin *silver* plate, which is more electro-negative, and gives, therefore, greater current power. The positions of the plates are also reversed, to save silver, there being a zinc on each side of the silver, and kept from touching it by strips of wood or cork. The zinc plates are bound together by a coupling, to which the connection from the next silver is fixed. Polarisation of plates may be lessened by covering the surface of the silver with finely-divided platinum.

(4.) *Daniell's Battery*, invented in 1826, was one of the first, and is still one of the best arrangements for constancy. It is a zinc and copper combination, the copper being in the shape of a jar, and serving as the outer dish of the cell.

Fig. 21 represents a Daniell's cell. The zinc, *z*, is formed into a rod, and is placed inside a porous jar, *d*, of unglazed porcelain or earthenware, which again stands inside the copper cylinder, *c*. In the porous dish, dilute sulphuric acid (one part acid to 10 or 12 of water) serves to excite the zinc. As a conducting and absorbent liquid, between the porous vessel and the copper, is put a *strong* solution of the blue crystals known as *sulphate of copper* or *blue vitriol.* Let us have a clear idea of the action of this sulphate of copper solution. It is a beautiful arrangement. Sulphate of copper is what is formed when sulphuric acid acts on copper; and chemistry informs us that, in the process, an atom of copper expels and takes the place of the atom of hydrogen which is present in each

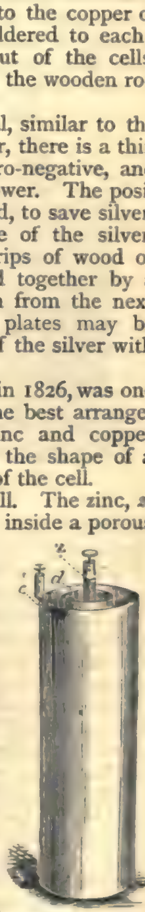


Fig. 21.

molecule of sulphuric acid. In ordinary circumstances, the affinity of the copper for the other elements of the sulphuric acid is greater than the affinity of the hydrogen for them. But when any gas is being set free from a previous combination, its *nascent* or new-born state is a most highly active one. Thus, the hydrogen which is being liberated, at the copper plate, from the water of the solution, is able to displace the copper in it, and return to the bosom of the sulphur and oxygen atoms to re-form sulphuric acid. The copper, deposed from its place, is thrown on the copper dish, and instead of hindering the action, as the hydrogen would do, keeps the surface bright with metallic copper, and so constantly fit for service.

The action of the battery is therefore to form sulphate of zinc in the porous dish, and to consume sulphate of copper in the outer. We must thus keep the solution saturated with sulphate of copper, by having some crystals of the salt lying at the bottom of the cell. Usually, there is a small shelf of copper gauze near the top of the copper vessel, on which crystals may be placed for this purpose.

(5.) *Grove's Battery* has a greater electro-motive power than any we have described, the plates being platinum and zinc; but it is inferior in constancy to Daniell's. Fig. 22 shews an excellent form of a Grove's cell. As in Daniell's, we have a porous dish, *d*, but containing, in this case, the

Fig. 22.

Fig. 23.

platinum plate, *p*, which is bent into the form seen in fig. 23, to increase its surface. Outside of *d* is the rolled-zinc plate, *z*, standing in a glass jar, *g*. The liquids used are dilute sulphuric acid in the outer dish, and strong nitric acid in the inner. When the poles are joined, zinc sulphate forms in the outer vessel, and an unhealthy gas (vapour of hyponitric acid) at the platinum plate, which must be kept from escaping by plugging the mouth of the porous dish. The nitric acid absorbs the hydrogen, and prevents polarisation of the plate.

Platinum is about four times the cost of silver, and that is the only objection to the battery. But it has the advantage of great power, and is very easy to manage; and the platinum does not get useless, as other negative plates do, by the action.

Iron, it is found, may be used for the platinum, with almost equal effect. Only, care must be taken to keep the nitric acid *concentrated*, as it is only then that it does *not* attack iron.

(6.) *Bunsen's Battery* was invented in 1843, and is most powerful. It differs, in principle, from Grove's only in the use of a *carbon* or *charcoal* electrode for a platinum one. In the original form, as devised by Bunsen, the carbon was in the shape of a jar, and the porous dish with its zinc stood inside it. But the modified form, most common here, is shewn in fig. 24. The carbon exactly takes the place of the platinum in Grove's element, and a greater quantity of electricity is obtained from the larger zinc surface. Bunsen's is the most energetic of all the constant batteries, and is almost universally employed on the continent. But it requires very careful preparation, and extreme care in making the carbon connections.

Fig. 24.

We need not describe the process of making the carbon plates, as they are now easily obtained, ready for use, from any electrician.

Recent Forms of Battery Cells.—The extensive use of the telegraph within the last few years has rendered the possession of a simple and cheap battery of good power very desirable. Many forms of cells have accordingly been suggested, and adopted with more or less success. We have here space to notice only those most favourably received.

(7.) The *Daniell Trough* has been adopted by the Post-office, and is said to be a good and economical battery. A wooden trough is divided into cells by glass plates, or varnished slate slabs. These are again subdivided by slabs of porous earthenware. Cast zinc plates and dilute acid go to one division, while copper and its sulphate go to the other. The action is, of course, identical with that of a Daniell.

(8.) The *Density Battery* of Calland is derived from Daniell's principle. Here the porous cell is dispensed with, and the two liquids are kept apart merely by their difference of density or weight. The copper plate is placed at the bottom of the cell among crystals of blue vitriol. A copper wire soldered to it, and protected by gutta-percha, passes up through the liquid to join the next zinc. Over the crystals of copper sulphate is poured a weak solution of sulphate of zinc, in which the zinc plate is suspended so as not to reach the copper solution. The zinc sulphate solution is lighter than the other liquid, and so floats on it without mixing. It is said to be very effective, and to give a constant current for months.

(9.) The *Minotto Battery*, somewhat like the former, has also come into telegraphic use. Coarsely powdered crystals of copper sulphate are placed at the bottom of the cell, the copper plate being under the crystals. A layer of clean sand (or even sawdust) is put over the crystals, with a piece of cloth or porous paper between, to prevent mixture.

The cell is filled with acid water, and a plate of

unamalgamated zinc laid on the sand, or hung perpendicular to the face of the copper plate.

(10.) The *Bottle Battery* of Faure must not be omitted, on account of its neatness and novelty. It is on Bunsen's principle, but no porous vessel is required, the carbon being at once the porous vessel and negative element. The carbon is made in the shape of a common bottle, with a carbon or platinum stopper to which the wire is attached. Nitric acid is put in it nearly up to the neck, and the stopper prevents the escape of nitrous fumes, which are both disagreeable and dangerous. The outside zinc is put in weak acid, as in Bunsen's cell, and the action is identical. Besides dispensing with the porous dish, this form is extremely convenient, and is superior in power to either Bunsen's or Grove's element.

(11.) The *Marié-Davy* or *Sulphate of Mercury Battery* is a Bunsen battery with another liquid in place of nitric acid in the porous dish. This is a solution, or paste, rather, of the white crystalline bisulphate of mercury. Sulphate of zinc is, of course, formed in the outer jar, while metallic mercury is deposited on the carbon, and, from its weight, falls to the bottom of the jar. Any sulphate of mercury passing through the porous dish will do no harm, as it will only amalgamate the zinc. The arrangement is powerful and ingenious, but it is rather expensive. A battery of eight cells gives as strong a current as twelve of Daniell's, but, with steady action, it falls much more rapidly than Daniell's. For interrupted work, such as telegraphy or ringing of bells, it is better suited, and will serve for three or four months.

(12.) The *Leclanché Battery* is the last we shall mention, as it is one of the most recent, and perhaps one of the most successful. It is a zinc-carbon combination. The carbon or negative plate is put in a porous jar, filled with a mixture of gas-coke or carbon, and the black dioxide of manganese. Both the carbon and manganese have first to be broken and sifted free from dust. For the zinc liquid there is a solution of common sal-ammoniac, or chloride of ammonium. Chloride of zinc is formed in the zinc dish, and this is soluble in the sal-ammoniac solution. In the other jar, the dioxide of manganese is reduced to a lower oxide, and ammonia is formed in small quantities.

This cell has great electro-motive power, ten of it being as powerful as sixteen Daniells, and it is thus specially suited for long lines of telegraph. It requires very little attention, and the zinc and chemicals need renewing only about once a year.

GALVANOMETRY, OR THE MEASUREMENT OF CURRENTS.

The magnetic, chemical, or heating effects of a current may, any or all, be taken as a measure of its strength. Sometimes one test is preferable, sometimes another. But, in general, the most convenient test of current strength is the extent to which it deflects a magnetic needle.

Nor does the needle only measure the strength; it also defines the direction of the current by the side to which it swings. Ampere's rule is a simple way of recollecting the connection between the flow of the current and the swing of the needle. It is this: *A person supposed to be swimming with the current in the wire, and having his face to the needle, sees its north pole turn to his left.* This always supposes the current-wire to lie in the magnetic meridian.

From this rule, it is obvious that a current passing *above* a needle turns it to the same hand as an *opposite* current does *beneath* the needle. But by *doubling* a conducting wire, so as to be over and then under the needle, we have clearly the same result. One current will then act twice on the needle, and each time to turn it to the same side. So, by bending the wire round and round the needle, and keeping the different turns separate, we can multiply the effect of the same current to any desired degree. This, then, is the principle of the *galvanometer multiplier*, or *galvanometer*. There are three forms of it on this principle.

(1.) The *Simple Galvanometer* consists of a magnetic needle poised or suspended delicately over a graduated card, and placed within a coil of *insulated copper wire*, so that its oscillations can be seen. Wire is insulated by being covered with gutta-percha, or by being overspun with cotton, or, far better, silk. This is found to be quite sufficient to prevent the current passing from one turn of the wire to another.

(2.) The *Astatic Galvanometer* is the form most commonly used; it is far more sensitive than the last. In place of a single magnetic needle, an *astatic pair* is employed. An astatic pair of magnetic needles is simply a pair of similar needles, with their poles turned opposite ways, and stiffly connected at their centres, so that both will swing together. The one tends always to turn in an opposite direction to the other under the earth's magnetic attraction. If, therefore, they were perfectly alike, we should have a perfectly *astatic* pair, or pair without *set;* that is, they would remain indifferently in any position, neutral to the direction of the earth's axis. It is impossible in practice to have a perfectly astatic pair; there is always more or less a tendency to *set* in one direction. The figure (fig. 25) shews how the astatic pair is used to form an astatic galvanometer. One needle swings within, and the other without the coil, and we have thus a double improvement on the single needle. First, the magnetic force constraining the needle to keep its north and south position is very small; only the difference of magnetism in the needles. Second, the current acts again on the outside needle, tending to turn it to the same hand as the inside one, as Ampere's rule at once shews. By such an arrangement, then, a galvanometer of extraordinary delicacy may be obtained. Fig. 26 shews the usual form which is given to the instrument.

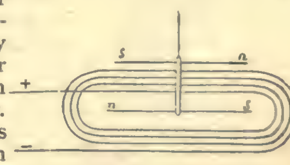


Fig. 25.

Round a bobbin, AB, of ivory is wound a coil of fine, silk-covered copper wire. The number of turns and thickness of wire depend on the use we are to put the galvanometer to. About six hundred or eight hundred does for all ordinary purposes, but for some delicate experiments as many as thirty thousand turns have been made. A slit is usually left in the coil, to admit the lower needle; and the upper needle moves over a

graduated circular rim. The whole is protected by a glass cover from the disturbance of the air,

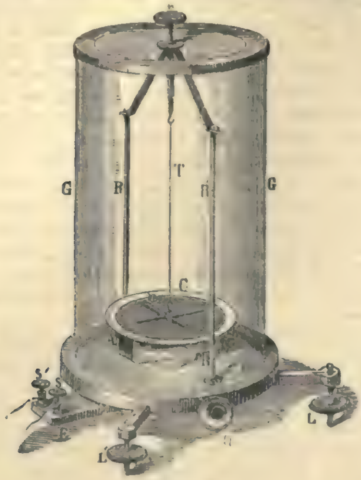


Fig. 26.

and rests on a stand supported by three screws, for levelling the instrument, that the needles may hang free. When used, the bobbin is turned round by the screw, Q, until the needle stands at the zero-point; and the wires through which the current is sent are fixed to the binding-screws, s, s', which communicate with the ends of the bobbin wire. The number of degrees that the needle deflects may then be read off, and this gives an idea of the strength of the current. It is to be observed, however, that twice as great a deflection does not shew twice as strong a current, because for different angles of deflection the coil is differently situated towards the needle. Still, we are sure that a greater deflection indicates a stronger current; and for about 20° on each side of the zero, the strength may be taken as proportional to the angle of deviation.

The third form of galvanometer multiplier is called the *Differential Galvanometer*. It is used for comparing the strength of two currents, and is a simple modification of the last.

For the description of other forms of current measurers, such as the *Tangent Galvanometer* and the *Sine Galvanometer*, the reader may refer to any of the larger treatises on the subject.

The *Reflecting Galvanometer* of Sir William Thomson is by far the most delicate of all our galvanometers. It was invented by him in connection with the Atlantic telegraph, and we shall describe it under *Submarine Telegraphy*.

Measure of Current Resistance.—Bodies differ to an almost incredible degree in the resistances they offer to the passage of a current. When a current has to face great resistance in its course, part of its power is spent in overcoming this resistance, and *disappears as heat*. Thus the current is weakened in the same degree as it is resisted; and it is *interrupted* when it is wholly *unable to overcome the resistance in its path.*

The determination of the relative resisting powers of metals is thus a matter of great importance. But it is also a matter of extreme difficulty, for temperature and purity of metal have a great effect on it. Thus $\frac{1}{8}$th per cent. of iron present in copper will increase its resistance to the current by as much as 25 per cent. Silver offers the least resistance of all our conductors, and copper the next smallest. The other metals follow in this order—gold, zinc, platinum, iron, tin, lead, mercury. Between silver and mercury there is a wide difference in resisting power; mercury offers fully sixty times the resistance of silver. But between the metals and liquids there is a yet wider difference. If copper offer a resistance of 1, then dilute acid offers a resistance of 1 million; a solution of copper sulphate, of 17 millions; and pure water has the almost incredible resistance of 6700 million times that of copper.

The law which the resistance of wires has been found to follow is, that it is greater the greater the length of the wire, and less the greater its area of cross section. Or, in more precise language, *the resistance is proportional directly to the length of a wire, and inversely to the area of cross section or square of its diameter.* Thus, we should have as strong a signal by a telegraph wire $\frac{3}{8}$ inch diameter, and nine miles long, as by one $\frac{1}{8}$ inch diameter, and only one mile long.

EFFECTS OF THE GALVANIC CURRENT.

These may be classified as mechanical, magnetical, physiological, heating, luminous, and chemical.

The first two classes of effects will be described under the distinct head of Electro-magnetism. We have seen that the physiological were the first observed effects of the current. They will be more particularly noticed under Animal Electricity, to which Galvani's experiment properly belongs. It is remarkable that when the current passes through the human body, nothing is felt except at the beginning and end of the current flow. It is the sudden change of tension that affects the nerves; and that is the reason why the frictional shock is more painful than the galvanic. A battery of even fifty Bunsen cells may be handled without much inconvenience. Only this is so far owing to the insulating nature of the skin. If we wet our hands with salt water, the effect is greatly increased; and a very *weak* current will be felt if we let it enter by a cut in the skin.

The senses may be readily affected by the current, especially those of taste and sight. If we put a half-crown under, and a piece of zinc above the tongue, a peculiar salt taste is perceived whenever we make them touch. When the pieces are put between the gums and the cheeks, a flash of light is seen each time they are joined. The nerves of hearing are not so quick, but with the poles of a battery of thirty cells inserted in the ears, it is said that a continuous noise is heard.

Heating Effects.—When a current passes through a thin wire, the wire becomes heated, more or less according to the strength of the current and the resistance of the wire. A fine steel wire, which offers great resistance, may be made white-hot, melted, or even dissipated into vapour. Even platinum, which cannot be fused by the heat of a furnace, may be melted and volatilised by a battery of thirty to forty Bunsens.

A useful application of the heating power of the current has been made to the firing of gunpowder. If the wires from a battery communicate with a fine steel wire embedded among gunpowder, the passage of a current will heat the steel red-hot,

and produce an explosion in a moment. This principle has been employed with great success in the construction of cartridges for use in blasting operations, and they have become very common on account of their safety and certainty of working.

Luminous Effects.—When the wires from a powerful battery are brought near to each other, no current passes till they touch. On separating them, a bright spark passes, due, as we shall afterwards see, to *induction.* Nor does the current cease after a *small* separation. It forces its way across the short interval of air, producing a brilliant light, and a heat so intense as to melt the most infusible metals. The ends of the wires will therefore be burned away, and we must seek for some more infusible conductor, in order that the current and the light may continue. This is found in the various kinds of carbon, such as charcoal, coke, &c. By far the best form of carbon for this purpose is the charcoal deposited in the retorts of gas-works. The carbon is formed into pointed

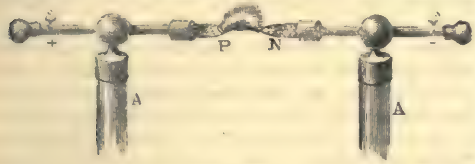


Fig. 27.

sticks or pencils, to fit two metal-holders such as are shewn in fig. 27. They can be adjusted to any distance by sliding-rods, to which they are fixed, and which communicate with the wires of the battery. When the current is on, and the points separated by one-tenth of an inch or so, a most dazzling light is produced, rivalling that of the sun in purity and splendour. It is too bright for the eye to examine it; but an image of the points can be cast on a screen, and then there will be seen, as in the figure, an arch of flame between the points. This arch of flame, or the *voltaic arc* of the electric light, is composed of white-hot particles of charcoal flying from the one pole to the other. The positive pole gradually gets hollow, while the negative remains pointed, apparently by the addition of matter.

The heat of the voltaic arch is the most intense that can be artificially produced. Platinum melts in it like wax in the flame of a candle. Quartz, lime, and magnesia are fused by it; and the diamond itself is not only fused, but reduced to a black mass like coke.

As the carbon points waste away, and the positive much more rapidly than the negative, some arrangement is necessary to keep the points at such a distance that the current can pass, and so the light continue. This is the object of the *electric lamp.* For an account of the principal lamps in which the voltaic arc is used, and the other species called *incandescent* lamps, see page 496 of the present volume.

Great progress has recently been made in methods for applying the electric light to the illumination of streets in cities; and its close rivalry has led to more economic and effective methods of using coal-gas, which for ease in use and cost has still for general purposes the superiority. The electric light has, however, been used for streets and public buildings. It has also long been used with excellent effect where a limited space had to be lit up for a few nights, as in the construction of bridges across rivers, and the like.

For lighthouses it is specially suited, and has been successfully adopted in many of them. That at Dungeness has been lit up with it since 1862; and that at La Heve, near Havre, since 1863. It is decidedly superior to oil-lamps in such cases, as its illuminating power is very great, and remarkably penetrating in hazy weather.

Chemical Effects.—When a current passes through a liquid, composed of two or more simple elements, there is in general a separation of the elements or a decomposition of the liquid. *Electrolysis* is the name given to this decomposition, the liquid so broken up being called the *electrolyte.*

The analysis of water by the current may be taken as the type of electrolytic action, and a very simple method of shewing this is seen in fig. 28.

Two slips of platinum are soldered to two copper wires, which are passed through a cork at the bottom of a glass basin. The basin is filled with water, slightly acid to make it conducting. Now when the platinum plates are connected with the wires from a battery, the liquid is polarised, oxygen going to the positive plate, and hydrogen to the negative. If the current be strong enough, these elements will be separated from the liquid, and as platinum combines with neither, each will bubble up at its platinum pole. They may easily be collected separately by filling two glass tubes with the acid water, and inverting them over the plates. Doing this, we find that the hydrogen is produced in twice the quantity of the oxygen; and we learn from this the important fact, that *elements are decomposed by electrolysis in the very same proportion as they are united in the compound*, for water, we know, has two atoms of hydrogen for each of oxygen.

Fig. 28.

Faraday called the two poles at which the elements appear, the *electrodes*, that is, electric ways, the positive pole being called by him also the *anode* (or *up* way), and the negative, the *cathode* (or *down* way). The element that goes to the anode he called the *anion* (or *up-going* one), and that to the cathode, the *cation* (or *down-going* one). In the case of water, oxygen is the anion or electro-negative element, and hydrogen the cation or electro-positive one.

It is to be noted that a *single cell* can never decompose water, or any electrolyte; at least two are required to overcome the polarisation of the plates or counter-current which the anion and cation tend to set up. The greater the strength of the current, the more rapidly are the elements liberated; and the quantity of gas given off corresponds exactly to the current power.

Faraday turned this to practical use as a *voltameter*, or current measurer, and its value is that

it gives us a *uniform standard* for comparison of currents. The gases are collected either together in a single vessel, or each in a separate one; the vessels are graduated, and the number of cubic inches of gas which a current gives in a certain time, say a minute, is an exact measure of its power.

Any other substances, if in a liquid state, composed of two elements, a metal and a non-metal, can be broken up by the current exactly like water.

The metal always corresponds to the hydrogen, and goes to the negative pole.

In the electrolysis of a solution of a salt, such as copper sulphate, we have an interesting case. If two platinum poles are put in a solution of this, pure metallic copper is deposited on the negative pole, and free sulphuric acid and oxygen appear at the positive; and layer after layer of fine copper-dust will be showered on the negative plate, so long as the sulphate of copper lasts.

In the same way with a solution of nitrate of silver, pure metallic silver will be deposited on the negative pole, and acid and oxygen on the other. All the common metals, gold, silver, platinum, copper, zinc, &c. can be deposited in this manner.

Electro-metallurgy is the practical application of this power of the galvanic current to precipitate a metallic layer on any surface which forms a negative electrode of a battery or cell. It is divided into two sections—*electro-typing*, where the coating of metal must be firm, and has to be removed from the surface, and *electro-plating*, when it is to remain fixed on the surface.

(1.) *Electro-typing* is the process by which seals, medals, engraved plates, ornaments, &c. can be most accurately copied, and reproduced in metal, more especially copper. We can best explain how this is done by taking a particular instance.

Suppose we wish to copy a seal in copper. An impression of it is first taken in gutta-percha, sealing-wax, fusible metal, or other substance which takes a sharp impression when heated. A wire to convey the current is stuck into the impression while soft, and, if the surface be non-conducting like gutta-percha, it is brushed over with plumbago or black-lead. Then it is attached by its wire to the negative or zinc pole of a weak Daniell's cell, while a plate of copper is attached to the other pole. The two are immersed in a strong solution of copper sulphate. Gradually, the copper from the sulphate is deposited on the black-leaded surface, until in a day or so a tolerably thick plate is formed. It may easily be detached by the point of a knife, and then we have a faithful copy of the original seal to the minutest line.

But we may even do without a battery cell altogether, and make a galvanic pair out of the object to be coated and a plate of zinc.

Electro-typing is of great importance to the engraver. Copper plates may be multiplied to any extent; and woodcuts, which would soon become useless, if printed from directly, can be converted into copper plates. Indeed, nearly all the illustrations in popular works are now printed from electro-types.

(2.) *Electro-plating* is the art of coating by the galvanic current the baser and cheaper metals, such as brass, bronze, copper, nickel silver, &c. with the more precious ones, such as silver and gold. Theoretically, the process is simple enough, but practically, it requires much experience and skill. When an article is to be electro-silvered, it is first thoroughly cleansed, and then washed with nitrate of mercury. This leaves a thin film of mercury, which acts as a cement between the article and the silver. It is then put in a silver bath, a weak solution of cyanide of silver in cyanide of potassium, and attached to the negative pole of a battery; while a silver plate is attached to the positive, to keep the solution, by its decomposition, from getting poor. The process of electro-gilding is very much the same; only the article first gets a layer of copper by electrolysis, and is then immersed in a gold bath. A piece of gold is suspended from the positive pole, and the bath must in this case be kept hot.

ELECTRO-MAGNETISM.

Hitherto, we have considered only the *internal* powers and properties of the galvanic current; we now pass to the effects produced by it *outside of its path*, that is, to its *mechanical* and *magnetical* effects. The former include the mutual attractions and repulsions of currents, and are usually treated of separately, as *electro-dynamics*. The latter include all the phenomena where magnetism is produced by the current, and form the subject of *electro-magnetism*. So closely allied, however, are the two, that the laws of the one class of effects can be deduced from those of the other. Electro-magnetism may thus be employed as including electro-dynamics.

The influence of currents on magnets, to which we have already referred in speaking of galvanometers, is mutual: magnets act on currents, attracting and repelling them just as currents do on magnets. Not only so, but currents also attract and repel each other according to very simple laws.

Now, so close is the connection between magnetic and current action, that there is no reason but to refer them to one and the same ultimate cause. Every case of magnetic action, whether of magnets on currents, currents on magnets, or magnets on magnets, can be at once explained by the theory that magnetism is due to electricity in current. Thus the laws of current action are at the foundation of electro-magnetism. They are two, though one is practically included in the other: (1.) Two parallel wires, capable of motion, or two flexible conducting chains, *attract* each other when currents pass along them in the *same* direction, and *repel* when they pass in *opposite* directions. (2.) Two wires or chains, not parallel, but crossing each other, attract when the current runs in *both*, either to or from the point of crossing, but repel when it flows in one to, and in the other from, this point.

These laws are easily proved by experiment with light frames of copper wire. They must be nicely movable upon pivots, and at the same time allow the current to pass round the frames without interruption. Many mechanical actions can be produced by the application of the two laws we have given. For example, a current flowing in a circle, may be made to cause a constant rotation of a wire conveying a current at right angles to the former.

A similar rotation may be produced by putting for the circular current, in the last case, a pole of

a magnet. In fact, the mutual action between a current and a magnet is of such a nature, that if either be fixed and the other movable, there will be a constant rotation of the one round the other; and a change in the direction of the current, or in the pole of the magnet, will reverse the direction of rotation.

Ampere's theory of magnetism furnishes the key to these actions, and forms the link between magnetism and current electricity. According to Ampere, magnetism is due to currents circulating round the particles of a magnet, and *all in the same direction.* The want of magnetism in a steel bar is simply owing to the currents flowing in all different directions, and so neutralising each other.

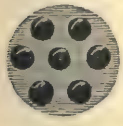


Fig. 29.

Fig. 30.

Fig. 29 shews a section of a magnetic bar with its currents all flowing one way. These are manifestly equivalent to one strong current flowing round the bar, as in fig. 30, for the internal currents destroy each other. Magnetisation is perfect when the currents are exactly parallel, and *coercitive force* is the resistance to this parallel disposal of the currents. Soft iron is more perfectly magnetic when under induction than steel, because iron has less coercitive force.

If this theory be correct, then we should find that circular currents should have magnetical properties. Experiment confirms the inference. When a current passes through a helix or spiral of copper wire it becomes exactly like a magnet. Each end has an opposite polarity; if suspended delicately, it will point north and south like a magnet; and spiral currents act on each other in every way as magnets do.

The nature of the poles is determined by the direction in which the current flows round the axis of the spiral. If, on entering the spiral, the current flow in a direction opposite to the hands of a watch, the spiral is said to be *left-handed*, and the N. pole will be as indicated in fig. 31. If it

Fig. 31.

go with the hands of a watch, it is *right-handed*, like a common screw, and the poles are as in fig. 32. This is in accordance with Ampere's rule;

Fig. 32.

for, if we imagine one swimming with the current and his face to the axis of the spiral, the N. pole is always on his left. In general, then, if we look along the axis at the pole of a magnet, it will be a *south* or a *north* pole according as its currents are seen to flow in the *same* or *opposite* direction to that of the hands of a watch.

Electro-magnets.—Perhaps the strongest proof of Ampere's theory is that a piece of soft iron, placed within a spiral current, becomes *for the time* powerfully magnetic. If bars of steel be placed inside, they are *permanently* magnetised; and a spiral current is thus a very ready and powerful means of magnetisation. Where powerful magnets are required, this is by far the best way of making them, and there is nothing easier: a few turns of insulated copper wire conveying a current will at once convert a steel bar into a magnet by passing it over the bar.

Magnets produced by the action of the current on soft iron are termed electro-magnets. They far outrival permanent magnets in strength; and their value lies in this also, that we can change their poles, or make their magnetism come and go in a moment, as if by magic. If the iron core be very soft, its power is gone the instant we stop the current.

Electro-magnets are generally made of the horse-shoe shape, as in fig. 33, and it matters not whether the coils be wound all over the magnet, or accumulated at the two ends. The power depends only on the number of turns of the coil, and the strength of the current. But there is, of course, a limit to the number of turns; for the advantage of increasing them may be counteracted by the weakening effect of the long wire on the current. The wire which is wound on the core should be thick, so as to be of small resistance, and covered either with silk or cotton. For ordinary sizes, the latter is sufficient, as the electricity most suited to develop magnetism is of small tension and easily insulated. Usually, it is wound, not on the core directly, but on two pasteboard cylinders or bobbins, which can be taken off the magnet at pleasure. With a very thick core, a sufficient number of turns, and a strong battery, we may have any power of electro-magnet. Some have been made capable of sustaining several tons weight. By far the largest that has ever been constructed is that just made for Lord Lindsay. It is said to weigh over 6 tons, and to have 14 miles of copper wire, ¼ inch thick, wound on its core. An equally colossal battery is now under construction for it. The battery will consist of 150 Grove's elements, each exposing a square yard of platinum surface. This gigantic size has never before been approached.

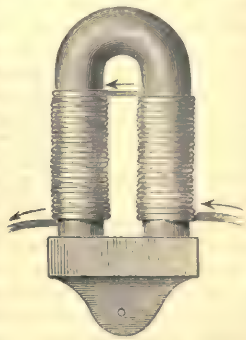


Fig. 33.

The application of electricity to the moving and regulating of clockwork will be found described in the number on HOROLOGY.

ELECTRIC TELEGRAPH.

By far the most wonderful and important application of voltaic electricity is the electric telegraph. The idea of transmitting a signal to a distance, by electricity conveyed along an insulated wire, had suggested itself long before it was practically carried into effect. An attempt was made to employ frictional electricity for this purpose, and the discharge of a Leyden jar was even effected

through two miles of wire. But the appeal to so fickle an agent was fruitless. It was only when the properties of the galvanic current became known, that a solution was found to the problem.

The essential parts of every electric telegraph are three. There must be, first, a *complete circuit* for the current to traverse, including one or more batteries for the generation of the current. Secondly, there must be a *communicator*, or means of producing the signals at the sending station. Thirdly, there must be an *indicator*, or apparatus for shewing the signals at the receiving station.

With regard to the first, there is not much variety or choice of contrivance. A single insulated wire is enough to put two stations in telegraphic communication. Although two wires were at first supposed to be necessary, it was soon found that the *earth* might be made to act the part of a *return wire* to complete the circuit. Thus the current passes from one pole of the battery through the communicator, along the insulated wire to the distant station. After producing the desired signals there, it passes to a large metal plate buried deep in the earth. A similar plate is sunk at the signalling station, and is connected with the other pole of the battery there. Now, we may either regard the earth between the plates as a huge conductor, allowing the currents from the opposite poles to neutralise—that is, as a real return path—or we may simply suppose that equal amounts of positive and negative electricities are drawn off at each end. The current depends on a constant neutralisation of the opposite electricities polarised at the opposite ends of the battery; and it matters not whether they neutralise directly, or the earth neutralise or drain off both together. In order to insure a proper draining off at each end, a very good earth connection, or 'earth,' must be secured, as in the case of a lightning-conductor. One good 'earth' serves for all the circuits of a telegraphic station.

There are three forms of insulation necessary, according as the wire is carried above ground, or under ground, or under water; and the three forms of line are named aërial, subterranean, or submarine, accordingly.

For aërial telegraphs, the wire is usually of galvanised iron, and is attached to glass or porcelain insulators, which are fixed to wooden posts some twenty feet high. Much attention has been paid to the manufacture of good insulators, as everything depends on proper insulation. A small loss or leakage at one pole may be inconsiderable; but in a long line, where thousands have to be taken into account, the loss may be so great, that only a small part of the current that sets out from the battery ever reaches the distant station.

Underground lines must have the insulation perfectly continuous, and the wire is, for that purpose, covered with gutta-percha or india-rubber. These lines are not much used, on account of the difficulty of 'faultless' insulation, the deterioration of the percha or rubber, and the expense of repairs.

In the case of submarine lines or cables, the very greatest care must be taken in the insulation. But on account of their importance, they will be specially described under Submarine Telegraphy.

The *communicator* assumes different forms according to the plan of the indicator or recording instrument. But the general principle is in every case the same. It is merely an apparatus for rapidly interrupting the circuit, and completing it again, or, in some cases, for rapidly changing the pole of a battery with which the wire communicates.

The *indicator* is perhaps the most interesting part of the telegraph, and the number of inventions connected with it is almost endless. In some, the signals are given by the deflection of a magnetic needle to the right or left. In others, again, they are given by mechanism connected with an armature of an electro-magnet. It sways to and fro under the action of the electro-magnet and a counter-spring, or between two electro-magnets.

Indicators of all kinds are either such as give merely a passing signal to the eye or ear, or such as permanently record the signals. *Cooke and Wheatstone's needle telegraph* is the best known of the former class, but it is now little used except in this country. At present, the form most widely used is of the second class, *Morse's recording telegraph.* It leaves, in point of simplicity and accuracy, little more to be desired. We shall, therefore, give the general arrangement of a telegraph chiefly on Morse's system.

Morse's recording instrument, or, as it is shortly termed, the 'Morse,' or Register, is shewn in fig. 34. L is the end of the line-wire which brings the current; E is the end of the wire which passes it

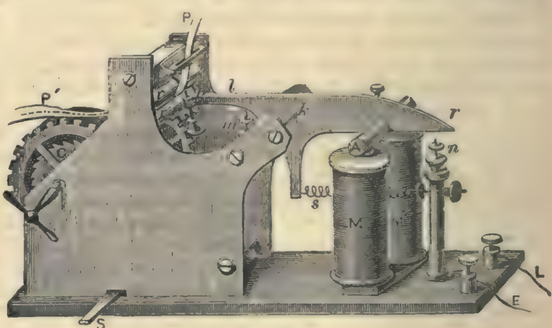


Fig. 34.

off to earth, after it has traversed the coils of the electro-magnet, MM′. When the current passes, and MM′ is magnetic, the soft iron armature, A, is drawn down, and thus the opposite end, *l*, of the lever *ll′*, to which it is attached, is forced up. When the current ceases, and MM′ can no longer attract A, the spring, *s*, brings back the end *l*; and as the current continues alternately to flow and to stop, the lever will keep oscillating between the stops *m* and *n*. At the end *l*, the lever carries a steel point or tracer, *p*, which, by the upward motion of that end, is brought against a strip of paper PP′. Now PP′ is carried towards P′ by the rollers *r*, *r′*, which are kept in motion by clockwork, quite independently of electricity. As long, then, as the pointer is pressed up, the paper strip is made to rub against it, and a line is thus embossed on its upper surface. To make sure of its doing this, there is a small groove in the upper roller, opposite the pointer. It is easy to see, then, that if the pointer press up for a moment only, a

dot will be imprinted, and if for a longer time, a line or dash. By a combination of dots and dashes, an alphabet is formed, the letters oftenest used being most easily signalled. Thus, E is one dot, and T is one dash; A is a dot and a dash, and I is two dots; and so on. But clerks do not spell out every word; they have a great many contractions, universally recognised. The paper is supplied from a large roll or bobbin (not seen in the figure) above the instrument, which turns round as the rollers demand. Of course, it is rolled off only while a message is being sent. When the clerk receives the signal for a message, he pulls out the switch, S, which liberates the clockwork, and sets the paper in motion. An experienced transcriber could easily make out the message though the paper never moved. In practice, he requires to look at the paper only when he has heard indistinctly, for the mere clicking of the lever has become to him a language perfectly intelligible, and it is much easier to hear and write than to look and write. But the printing of the message as well, relieves him of all responsibility as to its accuracy.

The *transmitting key* or *communicator* is seen in fig. 35. It is a brass lever, *ll*, with two nipples, *m*, *n*, one or other of which is in contact with one or other of the projections, *a*, *b*, according as H is pressed or not. The lever is in permanent connection with the line-wire L, *a* with the copper pole of the local battery, and *b* with the local

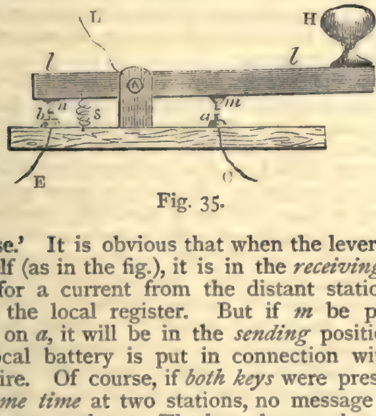


Fig. 35.

'Morse.' It is obvious that when the lever is left to itself (as in the fig.), it is in the *receiving* position, for a current from the distant station can reach the local register. But if *m* be pressed down on *a*, it will be in the *sending* position, for the local battery is put in connection with the line-wire. Of course, if *both keys* were pressed *at the same time* at two stations, no message could pass between them. The lever has a play of not over one-tenth of an inch on each side. This is quite sufficient to break contact, and it allows a very rapid manipulation. An expert telegrapher can transmit from thirty to forty words a minute.

How two Stations are connected.—The manner in which two stations are 'joined up' on Morse's system will be seen from fig. 36. Each station, S, S_1, is provided with its own communicator, indicator, and battery, included in the circuit in such a way that only one communicator and its battery, and the *opposite* Morse, can be in circuit at the same time. In the figure, S is supposed to be sending a message to S_1. Its key, *k*, is depressed, so that the current flows from the positive pole, C, of its battery to the key, and thence to a galvanometer *g*, included in the circuit, to shew the clerk that a current really passes. From *g* it passes through the wire LL to the receiving station S_1, where it passes first through a galvanometer, and thence to the key. The key, being in its natural position, allows the current to pass to the Morse, and there record its variations. Thence it passes to the earth-plate P_1, and is lost, while an equal amount of negative electricity is lost from the zinc pole at P.

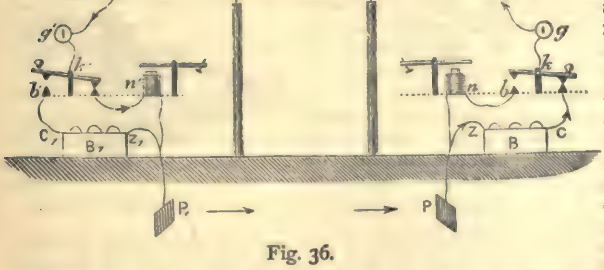


Fig. 36.

If *k* were left to itself, and *k'* depressed, then S_1 would be the sending, and S the receiving station, and the connections would be exactly as in the figure, only at opposite stations. When the clerk at S wishes to telegraph to S_1, he depresses the key several times, and sends a series of dots and dashes, giving the name of the station. The attention of S_1 is arrested by the clicking of the armature of his Morse, or, in some cases, by an alarm, which is made to ring till S_1 come and throw it out of circuit. He thereupon sends back to S that he is ready, and sets the clockwork in motion for the printing to begin.

Relay.—Hitherto, we have supposed that the recorder or Morse is worked *directly* by the line-current. This is only done on short circuits of less than fifty miles. There is so much leakage on a long line, that but a very feeble current

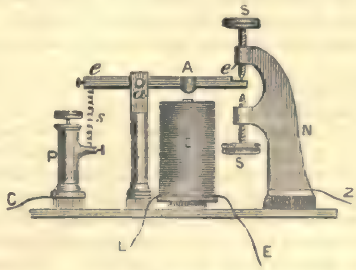


Fig. 37.

reaches the distant station; and to employ battery-power sufficient for direct working of the Morse, would be very expensive. In place, therefore, of passing the line-current through the Morse, it is passed through *a separate instrument*, called a 'relay,' which is much more sensitive than the Morse. It is shewn in fig. 37; and is simply an electro-magnet, E, with coils of very long fine wire, and an oscillating armature-lever, *eAe'*. A very feeble current is sufficient to magnetise the core of E, and to attract A, so that the interruptions of the current by the sending clerk will produce simply a series of oscillations of *eAe'*. Now, the zinc pole of the *local* battery is connected with the metal pillar N, and also with the screw S, but not with the screw S′, which is insulated from the pillar. A wire from the copper pole of the

local battery passes to the Morse, entering where the line-wire was supposed to enter in fig. 34, and a wire corresponding to E (in that figure) passes to the metal pillar, P, of the relay. Clearly, then, a current from the *local* battery will pass through the Morse, whenever a current from the distant station passes through the relay, and the duration of the one will exactly correspond to that of the other; for the local circuit is complete only so long as *e'* is drawn down on S. Thus, a current far too feeble to affect the Morse is sufficient to make the interruptions of a local circuit; and the result is precisely the same as if the Morse printed directly under the action of the line-current.

How several Stations are connected in one Circuit.—There are three ways in which a series of telegraph stations may be joined, so that each may send a message to another, and so that any one may send a message to all the rest at the same time.

The first method is called the *open circuit*, because the circuit is not completed except when the handle of *any* key is pressed down. Each station has a battery, which is brought into circuit by pressing down the key at that station. All the other batteries are out of circuit, and the current passes from the line-wire to the key, thence through the relay, and thence to the line-wire again, at each station without interruption.

Thus each may, if necessary, print a copy of the same message at one and the same moment. The interruptions of the current at the same instant in the different relays open and close the local circuits which include the Morses.

Second, there is the *closed circuit* method, by which the current *constantly* flows through all the keys and relays, *while no one operates.* A single battery at one of the terminals, or, better, one at each end, is quite sufficient for the whole series. The circuit is broken by any one key being pressed down.

A third method is adopted for long lines. It is called *translation.* The two methods of *open* and *closed circuits* are only for short lines of not more than 200 to 300 miles. When two stations, 500 miles or more apart, are communicating, the transmission is generally broken at one or two stages on the way, and retransmitted. This fresh transmission is done *mechanically*, without requiring any attention or hand-labour. The lever of the Morse is made to act as a relay to open and close the current transmitted from a *fresh* battery at its station. Thus, the Morse may register a copy of the message itself, while it serves at the same time to send it on to the next stage. All the intermediate stations may, of course, print copies of the message at the same time. It is in this way that parliamentary news is transmitted from London to all the important towns between it and Edinburgh or Aberdeen.

Cooke and Wheatstone's Needle Telegraph is the most common of non-recording instruments. It is nothing but an upright astatic galvanometer, with the needles loaded, to keep them vertical when at rest. The deflections of the needle to right or left, by the passage of the current through the coils in one direction, or the reverse, constitute the signals. All that is seen of the communicator outside the instrument is a handle under the dial. This handle turns a cylinder inside, which acts as a commutator or current-changer. When the handle is upright, it is in the receiving position, and allows the current from the distant station to pass to the coil of the galvanometer. But when the handle is turned to one side or another, it shuts off communication of the distant battery with its coil, and puts its own local battery in connection with the line-wire, and therefore with all distant stations whose communicators are in the *receiving* position. The needles deflect to right or left accordingly, both at the sending and at the receiving station. A combination of these right and left deflections is used as an alphabet. Thus, A is made by two left deflections; B, by three; M, by one right; R, by one left, then one right; and so on. This is the old way. Now, however, it is usual to adopt an alphabet corresponding to Morse's. A turn of the handle to the right, or of the needle to the left, corresponds to a dot; and a turn to the opposite hand, to a dash. (See fig. 45).

No relay is needed in this case, as the galvanometer needle is sensitive enough to be worked directly by the line-current. Several stations are connected on the *open circuit* arrangement.

There are many other forms of indicator that we have not space to describe. Perhaps the most wonderful contrivances in this branch of telegraphy are the *Type-printing Telegraphs.* That invented by Hughes of New York, in 1859, was one of the marvels of the last Paris Exposition. It actually prints the message in Roman characters on a strip of paper. Its construction is rather complicated, but others of simpler character have lately been invented.

Submarine Telegraphy.—The subject of ocean telegraphs has of late years assumed the greatest importance. From the first unsuccessful attempt at cable-laying, which was made in 1850 between Dover and Calais, to the achievement of laying the Atlantic cable in 1866, was a great stride in so short a time. Many difficulties, seeming at one time almost insuperable, have been overcome, and now the manufacture and management of cables are all but perfect. The points to be secured in their construction are mainly three. First, the insulation must be perfectly faultless, for the smallest flaw is infinitely more serious than in the case of land-lines. Second, the cable must be strong enough to bear the weight of a considerable length of itself, and to resist chafing on rocks and inequalities of the ocean-bed. Third, the very best conducting-wire must be used for the transmitting core, on account of the extremely feeble current which reaches the end of a long cable, even when the insulation is complete.

The construction usually adopted to satisfy these requirements will be understood from fig. 38, which shews (full size) the 'make' of the Malta and Alexandria cable.

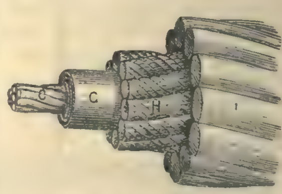


Fig. 38.

The core, C, is a strand of seven copper wires, embedded in an insulating substance, called Chatterton's Compound (= 1 part Stockholm tar, 1 part resin, 3 parts gutta-percha). A strand of wires, though not so highly conducting as a solid wire of the same diameter, is

preferred, because it is less likely to break. Covering the core are three layers of gutta-percha, G, with Chatterton's Compound between each. Over the percha is a coating, H, of tarred yarn, to act as a padding between the insulating material and the external sheathing, I. This consists of eighteen wires of galvanised iron, laid on spirally. It has to bear the strain of 'paying out,' and to protect from roughness of sea-bottom.

The two Atlantic cables, laid in 1865 and 1866, do not differ in any essential from the one described. Their external diameter is 1⅛ inch, and the sheathing consists of ten steel wires, each of which is separately surrounded with five strands of hemp. In water, they weigh about fourteen hundredweight per nautical mile, and each cable would bear about eleven knots of itself in water without breaking. Thus the difficulties of obtaining sufficient strength and insulation have been wholly overcome.

But there remains a more perplexing difficulty still. It is seen on very long land-lines; only it can be easily met in them by retransmission. The difficulty lies here. What is given as a momentary signal at one end of a cable, *oozes* out as a prolonged signal at the other. Time must thus be given for each signal to ooze out before another is sent; and the result is a great delay in the transmission of messages. Sir William Thomson has found that the greatest speed of signalling possible on an air-line, of iron wire ¼ inch diameter, and two thousand miles long, would be twenty words a minute. Now, with the two thousand miles of Atlantic cable, laid in 1858, the greatest speed attained was only 2⅓ words a minute, though its core was a better conductor than the ¼ inch iron wire. The cause of this extraordinary retardation of the current is usually ascribed to an *inductive* action of the water surrounding the cable. In fact, the cable is just an enormous Leyden jar, with its core for the inside coating, the gutta-percha for the dielectric, and the water and sheathing for its outer coating. When a signal is sent, but a very small part of the current instantly reaches the other end. The rest is absorbed on the way, bound as a statical charge by the electricity it has induced on the water. The gradual oozing out of the electricity stored up in the cable, after cutting off the battery connection at the signalling end, is like the residual charges of a Leyden jar. What should come out at the other end as a short, sharp discharge, comes drawling out as a series of them.

No way of preventing this inductive action has yet been found, except thickening the core and insulation. But, of course, only a certain weight of cable can practically be laid. Yet, though it cannot be prevented, its effect on the signals has been in a great measure obviated. The energy and genius of such men as Sir W. Thomson, Mr Varley, Mr Siemens, and others have wrought wonders.

First of all, the statical charge can be got rid of to a great extent in this way. After sending a short signal, the clerk sends a second of opposite name by rapidly reversing the poles of the battery which are connected with the cable. This sends a wave of opposite kind to the first, which serves to counteract its inductive action, and discharge the cable. More than one may be required. For the Atlantic cable, for instance, five signals were considered necessary to completely discharge it: first, a wave from the copper pole, then one half as long again from the zinc, then one from the copper four-fifths of length of the first, and so on.

Next, and not less important, is the invention of a sufficiently delicate indicator to be affected by the extremely weak current which escapes induction. This is found in Sir William Thomson's *Reflecting Galvanometer*, which was adopted for the Atlantic cable. Fig. 39 will give an idea of it. The current is passed through a *small* vertical coil, D, of fine wire, in the centre of

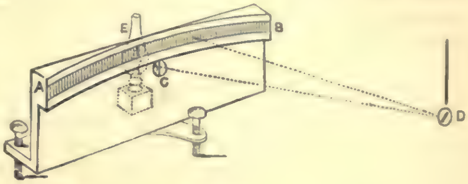


Fig. 39.

which swings a short magnetic needle hung by a silk fibre. The needle carries a small hollow mirror, and, mirror and all, only weighs about a grain and a half. At a distance of two or three feet from the mirror is a solid wooden stand, with a graduated scale, AB, forming part of a circle facing the mirror. In the stand, just under the centre of the scale, a hole, C, is drilled, and a fine wire stretched upright across it. A strong lamp, E, stands behind the opening, so that its light will fall on the mirror, and be reflected back on the scale. An image of the wire will thus be constantly thrown on the scale, and the slightest motion of the needle and its mirror will produce a much greater motion of the image index. As the current flows one way or another, the index will move to one side or another, and thus an alphabet may be formed as with the common needle telegraph. The Morse system is adopted, a dash corresponding to a right, and a dot to a left deflection of the image. To make it come quickly to rest after a deflection, a magnet is placed near the needle, and in this way a very delicate and quick indicator is got.

To the ingenuity of the same inventor is due an *ink-recorder*, which marks the right and left deflections on a paper ribbon. Here the *coil* is movable, and the magnet fixed. The coil is of very fine wire, and is delicately hung between the poles of a strong horse-shoe magnet, and so that the current from the cable can pass through it. It will turn to one side or another, therefore, according to the direction of the current through it. In front of the coil is placed an insulated vessel filled with common ink. Into this dips a very fine glass siphon, the leg of which is attached to the fine coil, and is made to turn with it. It is clear, then, that if ink issue from the siphon, it will trace a straight line (on the paper which passes under it) so long as no signals flow. But a signal will bend the line to one side or another according to its direction. By a very ingenious idea, Sir W. Thomson avoids the rubbing of the siphon against the paper. He keeps the vessel and ink constantly electrified, say positively, and the paper which passes under the end of the siphon also negatively. This produces

a steady flow of ink in a fine stream, just as in the case of the 'electric pail.'

As a proof of the skill and genius brought to bear on the Atlantic telegraph, and of the delicacy of Sir W. Thomson's instruments, it may be mentioned, that a tiny cell, consisting of a copper percussion-cap and a small piece of zinc, has been found sufficient to send a message across the Atlantic. In spite of all the difficulties of the case, signalling is now done as rapidly through it as on any land-line of the same length. Public messages are sent at the rate of eight to fourteen words a minute; but when the clerks communicate with each other, as high a speed as twenty words a minute is attained.

ELECTRICITY OF CURRENT INDUCTION.

Faraday discovered, in 1832, that current electricity may be developed by induction, in a manner somewhat analogous to that in which statical electricity is induced. If a wire, through which a current passes, be brought near to another whose ends are fixed in the binding-screws of a galvanometer, there is an instant deflection of the needle. It soon falls back, however, to its original position, and not the slightest effect is seen so long as the current continues steadily to flow. On withdrawing the wire, or on stopping the current, we again have a deflection of the needle, but this time to the other side. As often as we join and break the current, we have these momentary flows of electricity induced in the galvanometer wire, which will set the needle a-swinging from side to side.

In general, then, it may be stated that the passage of a current in a conducting circuit produces a sympathetic electric state in a neighbouring circuit; so that any change of condition of the first is accompanied with a corresponding electric throb of the second. The effect on the galvanometer circuit will be greater the more rapidly we change the state of the inducing electricity, and the greater the extent of the second circuit influenced by the current.

We must note the directions of the induced currents. By the *approach* or *commencement* of an inducing or *primary* current, a wave passes in an *opposite* direction through the induced or *secondary* circuit; and by the *break* or *withdrawal* of the primary current, a wave passes along the secondary circuit in the *same* direction as that of the primary. Or, shortly, *at make and break of primary circuit, an inverse and a direct secondary current are respectively induced.* There is thus a great difference between current and statical induction. So long as the prime conductor of a machine is charged, it has a *constant* inducing influence on all bodies near it. But it is only a change of *tension* in current electricity which has any inducing power, and the power is momentary as the change.

We shall now describe the method of producing these currents adopted in practice. The *induction coil* is the apparatus employed for this purpose, and the best form of it is that known as *Ruhmkorff's coil.*

Essentially, it consists of two bobbins or coils of insulated copper-wire, an inner and an outer. The inner coil is of thick wire, and through it passes the primary or battery current. It is called the primary coil. The outer is of fine wire, and in it is induced the secondary current, at make and break of the primary circuit. It is called the secondary coil. Sometimes the inner coil is made so that it can be withdrawn from the secondary at pleasure.

The object of this coil-arrangement of the wires is to make each turn of the primary or inducing wire act not only on the turn of the secondary next it, but also on all the turns near it. A vastly greater effect is thereby obtained than if the two wires were simply laid side by side in a straight line. For this reason, too—that the strength of the induced currents depends on the extent of secondary wire under the influence of the primary—very fine wire is used, to give as great a length of it as possible. Induced currents are of high tension compared with battery currents, and the fineness of the wire is no obstacle to the passage of the currents. Only, the finer the wire, and the higher the tension of the secondary currents, the more careful must be the insulation of the different turns and layers. Everything depends on the proper insulation of the secondary coil.

We have said that the wire of the primary coil is *thick.* This is to offer little resistance to the battery current, and to give the maximum of magnetic effect. For the inducing power of the primary increases with its magnetic power. In proof of this, it is found that the addition of a soft iron core in the primary coil increases enormously the strength of the induced currents; and we know it heightens the magnetism of the inducing coil. In further proof of this fact, and in singular confirmation of Ampere's theory of magnetism, a permanent bar-magnet may be put for the primary coil. A current in one direction, or the reverse, is induced when it is put in or taken out of the secondary coil.

Such are the general features of the induction coil. Fig. 40 will give an idea of its appearance. The primary coil is inside and out of view, and

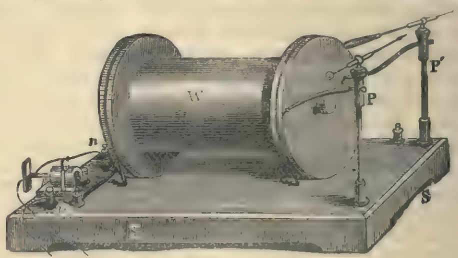


Fig. 40.

the secondary, W, alone is seen. The ends of the secondary wire are soldered to two brass heads, P, P', insulated on glass pillars, and carrying pointed brass rods, capable of universal motion. It is between these brass points that the induced current leaps across. The two battery wires are attached to the two binding-screws, *p* and *n*. Before reaching the coil, the current has to pass through, first, the commutator, C, and, second, a self-acting break not seen in the figure. With the commutator we can turn the current off or on, or reverse it at pleasure, by giving it a quarter or a half turn.

The automatic break interrupts the current with extreme rapidity, and so gives rise to an incessant stream of induced currents.

Extra Currents.—Not only does a current induce electricity in a neighbouring circuit, but it also acts inductively on itself. If we break a current passing through a *long* wire, we observe a bright spark at the part broken. This is very feeble if the wire be short, but very brilliant if it be long, and especially if it be wound in a coil. Obviously, it is not owing to the current being strong, for we know it is weaker the longer the path it has to traverse. The cause has been found to be due to *extra currents* in the wire, produced by the various parts of the wire circuit acting inductively on each other. They are *direct* when the current *stops*, and *inverse* when it *begins*. The effect of the *inverse* current, induced in the circuit when it is joined, is to oppose and so retard the instantaneous passage of the main current; while the *direct* extra current, which follows the break of circuit, has a very weakening effect on the tension of the *secondary* current, if it is allowed to pass by spark or otherwise. This is because it has itself a very high tension, and it tends to prolong the current in the primary wire, and so impair the suddenness of the break, on which the tension of the induced current depends.

The *condenser* is an important addition to the coil, and serves to get rid of the extra current, which, as we have said, forms in the primary wire. It is placed in the sole S, and does not meet the eye. It is simply a number of sheets of tinfoil separated by layers of oiled silk, the odd ones being all connected in one set, and the even in another. Each set communicates with an end of the primary wire, and acts like a coating of a Leyden jar. The whole, in some way or other not well explained, absorbs the extra current, and suppresses its injurious effects on the secondary current.

Some enormous induction coils have been made in recent years, the most powerful being one made for Professor Pepper. There are in it more than two miles of primary wire, and no less than 150 miles of secondary. The iron wire core alone weighs over a hundredweight, and the whole coil about three-quarters of a ton. It is said that, with a powerful battery, a spark of fully two feet can be got from it.

The electricity of the induction coil is more of the nature of the frictional than of the galvanic excitement. The sparks which pass between the 'points' are very like those of the machine, especially if the points be some distance apart. As with common electricity too, the physiological effects are very marked, and are a familiar object of exhibition. The beautiful luminous effects obtained by passing ordinary electricity through rarefied air or different gases, are shewn yet more brilliantly with the induction coil.

On the other hand, the induced current has little power to deflect a magnetic needle, or to effect chemical decomposition. All this shews that the electricity of induction may have enormous intensity or tension, and yet no great quantity; for we know that magnetic and chemical effects are due to electrical quantity only.

In fact, the secondary current is as deficient in quantity as it is superior in intensity to the primary current. Or, in the language of the day, the total energy of the primary current is exactly equivalent to the total energy of the secondary: the kinetic (or actual current) energy of the former is transformed into potential energy of the latter; the potential energy of the primary is small, as is the kinetic energy of the secondary. Induction is a signal example of the conversion of kinetic into potential energy.

MAGNETO-ELECTRICITY.

We have already seen that the action of the primary in induction coils may be exactly replaced by that of a magnet. The approach and withdrawal of a permanent magnet induces two powerful opposite currents in a coil. If, then, we had some means of rapidly removing the influence of the permanent magnet, as we had of the primary coil, by breaking its current, we should have induced electricity from magnetism, and altogether independent of galvanic batteries.

We shall now describe the usual mode by which such magneto-electricity, or magnet-origin electricity, is obtained. Fig. 41 represents one of the simplest forms of magneto-electric machines. NS is a large fixed steel magnet, and BB is a bar of soft iron, which, with the pieces of soft iron under the coils C and D, forms a sort of bent armature to the magnet. Now, it is evident that, as the armature turns round from being in line with NS, there will be first a gradual decrease of magnetic power in its cores, during a quarter of a turn, and then a gradual increase during the next quarter, till CD is again in line with NS. But the decrease of magnetic influence, or the withdrawal of it, induces a current in a coil; and the increase or approach of a magnet induces an opposite current in a coil. Thus, then, as CD turns round from the line of the poles, currents will be induced in the coils, if the two ends of the wire are joined. They will not be produced abruptly, but in a constant stream, as the change of magnetic influence is gradual; and during the first quarter of a turn they will be all in one direction. During the next quarter there is a gradual increase of magnetism in the cores, and this would produce currents in an opposite direction, were it not that there is also a change of poles. This double reversal, therefore, gives currents induced in the same direction as during the first quarter. So, then, during the first half-revolution from the line of the poles, a constant stream of currents is generated all in one direction. In the next half-revolution, the whole state of matters is of course reversed, and we shall have a current flow in the opposite direction. We have merely to introduce a commutating piece, F (which allows the springs, H, K, alternately to

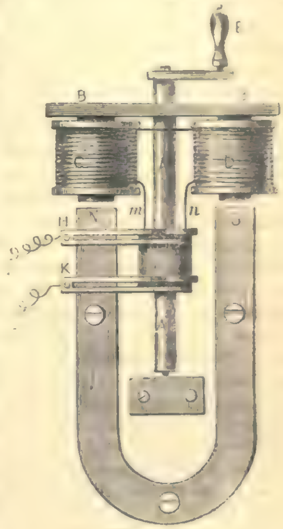


Fig. 41.

communicate with the ends, *m*, *n*, of the coil), to give us a constant flow of electricity in one direction.

With electricity obtained in this way, we may have all the ordinary current effects. Water may be decomposed, platinum wire heated red-hot, and soft iron magnetised. It has been much used for medical purposes, and the physiological effects are very powerful. Magneto-electric machines have also been used for firing gunpowder. *Abel* has lately constructed fuses which may be readily fired with a pocket-machine of this kind.

Such a machine forms a link of the chain that binds all the physical forces together. The force of a magnet, and the force of a man turning a handle, may seem very different, and they do differ widely. Yet they differ only in *form*. With a suitable arrangement, the one form of energy may be, as it were, remoulded and brought forth in the shape of the other.

Recent Magneto-electric Machines.—The magneto-electric machine has now come into extensive use, as being a readier, steadier, and cleanlier source of current electricity than the galvanic battery. Very powerful machines have been constructed on much the same principle as that we have just described. They have been employed for the electric light in lighthouses, and are driven by small steam-engines. We are to look upon them as simply the means of converting mechanical into electrical force or energy. But important modifications in the construction of these have been made in recent years.

Siemens' Armature.—In 1854, Siemens introduced a new form of armature, which brings the coil and its core nearer the poles of the inducing magnet or magnetic magazine. It has the wire wound *lengthways* or *parallel to the axis of its core*, and not across its length, as in common electro-magnets. The core is a cylinder of soft iron, with a large hollow scooped out on each side, leaving it somewhat like a piece of an iron rail. Insulated copper wire is wound along it till this hollow is filled up, and the cylindrical form restored. The *faces* of the core or rail, and not the ends, form the poles of this electro-magnet. It is not rotated *before* the poles of a steel magnet, as in the common machine, but *between* the poles of a series of magnets spanning it like a bridge, whose breadth is the length of the armature. A very rapid rotation can be given to the cylinder round its axis, and the iron faces are magnetised and demagnetised with corresponding rapidity.

Wilde's Machine.—Wilde of Manchester constructed in 1865 a magneto-electric machine of unequalled simplicity, which can be made to convert any amount of mechanical energy into electricity. It is formed on a new and seemingly paradoxical principle—namely, *that the weakest current or magnet may be made to induce any desired strength of current or magnet.*

Wilde's machine consists of two magneto-electric machines, a small one surmounting a large one of precisely similar principle, but of enormously greater strength. The figure (fig. 42), represents an end view of the machine. In the small machine, the inducing power is a magnetic magazine, *m*, of twelve to sixteen steel horse-shoe magnets. It evokes currents in a Siemens armature, which revolves between the poles, *a*, *b*, of the magnets, some 2500 times a minute. Two springs, connected with *n* and *p*, press on the commutator of the Siemens, and are the poles of the upper

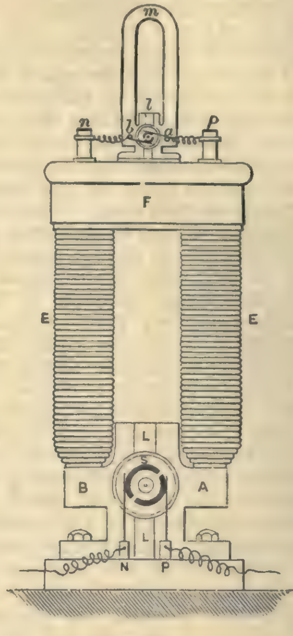


Fig. 42.

current. This current is not used directly, but is sent through the coils, E, E, of the huge electro-magnet of the lower machine. It has a Siemens armature, S, revolving between its poles, A, B, some 1800 times a minute. Both machines are precisely alike in action, and differ only in power. The armatures are both driven by belts from the same shaft. The arrangement of the magnetic poles is very ingenious. It is the same in both, but we shall refer only to the lower. They consist of two masses of soft iron, A and B, hollowed out so as to form the two sides of a tube to inclose the Siemens armature. Pieces of brass, L, L, serve to insulate the two poles magnetically, and to complete the tube. This protects the armature from the resistance of the air, and brings it as near as possible to the inductive influence of the poles.

The effects which this machine is capable of producing are almost incredible. When worked with a three horse-power engine, the current of the second armature consumes carbon sticks three-eighths of an inch square, and evolves a light of insupportable brilliancy. With one that consumes carbons half an inch square, a light so intense is got that, when put on a lofty building, it casts shadows from the *flames* of street-lamps, a quarter of a mile away. Mr Wilde succeeded in melting an iron rod fifteen inches long, and a quarter of an inch thick. Wilde has even employed the current of the second armature to magnetise a second electro-magnet still more powerful than the first. The whole required a fifteen horse-power engine to drive it, and the heat of the current was sufficient to melt a platinum bar two feet long and a quarter of an inch thick. Indeed, the only limit to the amount of electricity which might thus be

obtained, is the mechanical energy required to be expended.

Several modifications of Wilde's principle have been introduced within the last few years by Siemens, Wheatstone, Ladd, and others. Ladd's improvement makes the machine more convenient and simple in form, and promises to make it more popular. Theoretically, these machines are examples of the mutual convertibility of heat or mechanical energy into kinetic electric energy, and of this again into the energy of mechanical force or of heat and light.

THERMO-ELECTRICITY.

As the electric current produces heat, so we may invert the order of the phenomena, and from heat derive electricity. When any two metals, unequally susceptible to heat, are soldered together, and heated at the joining, an electric current is evoked. The two metals which shew this property most readily are *antimony* and *bismuth*. Thus, if a bar of antimony, A (fig. 43), be soldered to a bar of bismuth, B, and their other ends connected with a galvanometer, G, a current will pass when we heat the junction, S. Inside the couple, it flows from bismuth to antimony, and outside from antimony to bismuth, as we know by the side to which the needle swings. If any two of the following metals be joined in this way as a thermo-electric pair, a current will flow, *at the heated junction*, from the one which occurs first in the list to the other—bismuth, nickel, lead, tin, copper, platinum, silver, zinc, iron, antimony, tellurium.

Fig. 43.

If *cold*, instead of heat, be applied at the junction of two metals, it will produce a current opposite in direction to what the heat would. When we plunge the antimony-bismuth couple in ice-water, a current flows *from bismuth to antimony* in the outside wire. One antimony-bismuth pair has little power, but several may be joined, just as in a galvanic battery. Fig. 44 shews the arrangement of such a thermo-electric pile or battery. Obviously, only the odd junctions must be heated, for if all were, there would be no current at all. The current is from bismuth to antimony when a junction is heated, and from antimony to bismuth when it is chilled. Thus the strength of current produced will depend on the difference of temperatures in the two sets of faces. A pretty strong current may be evolved by keeping one set of junctions in ice, or a freezing mixture, and the other in boiling water. The electro-motive force is, however, very weak compared with that due to chemical action. In fact, it takes about one hundred and fifty bismuth-antimony pairs to give the electromotive force of a single Daniell cell, one set of joints being kept at the freezing, and the other at the boiling point of water. For this reason, heat is not available as a convenient source of electricity by any of the means yet discovered.

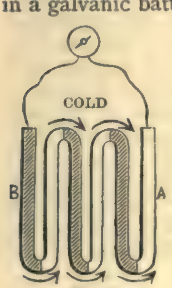


Fig. 44.

It is as a thermometer that the thermo-electric battery has its most important application. When employed for this purpose, it is called a *thermo-pile*. To form it, some twenty or thirty antimony-bismuth pairs are connected as in a battery, and compactly put together with varnished paper between the sides. The whole is inclosed in an insulating tube, so that only the junctions are exposed at each end, and these are blackened, to increase their absorption of heat. Wires connect the end plates with an astatic galvanometer, whose coil must be of *short thick wire*, on account of the feeble tension of heat-excited currents. If either face be heated, a current will arise: if one be heated, and the other cooled, the current will be stronger; but if both be heated alike, there will be no current. So sensitive is such an instrument, that the mere approach of the hand or of a piece of ice, though at a considerable distance, is sufficient to deflect its galvanometer needle. For experiments on radiant heat, this instrument is most important, and now supersedes all others.

A curious effect was observed in 1834 by Peltier, and is sometimes known as the Peltier effect. When a feeble galvanic current is sent through an antimony-bismuth pair, in a direction from bismuth to antimony, and the junction is immersed in water, cooled down to the freezing-point, but not frozen, as much cold will be developed as will make the water freeze. Heat will be produced if we reverse the current, and the water will not then be frozen. In a series of pairs the junctions will be alternately heated and chilled. Only the current must not be too strong, else the whole will be heated.

All these facts have been shewn to be in complete accordance with the modern doctrine of the conservation of energy. If the two faces of a thermo-pile be kept each at a constant temperature, a constant current flows, in the antimony plates, from the warmer junctions to the other; and the energy of the current is an exact equivalent of the excess of heat-energy absorbed at the warmer over that given out at the colder junctions. If the current be not converted into magnetical, mechanical, or chemical force, the heat energy will be entirely recovered as heat in the circuit. But if the current be used to do any work, a corresponding amount of heat will be withdrawn from the circuit.

ANIMAL ELECTRICITY.

The tissues and organs of animals are not only affected by the electric spark and current, but they are themselves also a source of electricity. In general, the strength of their electro-motive power is so feeble that it requires special experiment to detect it. There are, however, some species of fishes which exhibit such a power very readily.

It was long ago known that a certain kind of flat fish, somewhat like a skate, and found on the shores of the Mediterranean, produced a numbing sensation in the arms of the fishermen when they handled it. The Romans called it *torpedo*, from a word meaning to 'benumb,' and this name is now usually given to the whole genus to which it belongs. It has regular electric organs or batteries, placed on each side in the spaces

between the pectoral fins, the head, and gills. Each battery consists of a number (varying according to age) of hexagonal prisms, somewhat like the cells of a honeycomb. The double set of organs is completely under the control of the torpedo; it can give a shock similar to that of a Leyden jar; and Matteucci has even obtained sparks from it.

Among other kinds of fish with a similar power, the most noted is the *Gymnotus electricus*, or electrical eel, found in the rivers of Bengal and Surinam, and common in all the streams flowing into the Orinoco. It is from three to four feet in length usually, though it has been found even six feet long. The whole of its viscera and digestive organs lie near the head, the rest of the body being taken up with the electrical apparatus. This consists of four batteries—two on each side, and placed one above the other, the upper being the larger. The batteries are made up of a number of piles, looking very like galvanic troughs, and numbering from thirty to sixty in the upper, and from eight to fourteen in the lower battery.

Faraday experimented, about 1840, on a specimen of this eel, exhibited in the Adelaide Gallery, in London. The shock which the animal was capable of giving was very great, equal to that of a good-sized Leyden battery. It was strongest when one hand communicated with the head, and the other with the tail, and it was sufficient to stun or even kill fish.

In all such cases we have the extreme of electric development in the animal system. But apart from special organs, living nerve and muscle have an electricity of their own, which fails as life dies out, and is wanting altogether after death. Much attention has been given of late years to this electricity of muscles and nerves; and the discoveries of Du Bois-Reymond, Matteucci, and others, have given the study a title to be regarded as a branch of physical science.

Galvani must, however, be credited with being the father of the science. Frog-limbs, as prepared by him, are still one of the best means of shewing not only the effect of galvanic action on the animal frame, but also the existence of an electro-motive force in the frame itself. Galvani proved that two metals in contact are not required to cause convulsions in the frog-limbs. A single wire joining the spinal nerves with the muscles of the leg causes sensible convulsions, and he argued from this the existence of muscular and nervous currents.

The existence and principal laws of such currents are now beyond a doubt; but we are still in darkness as to their real origin, and their analogy to other known sources of electricity.

In living animals, or in those very recently killed, there is always a current flowing from the interior of a muscle or of a nerve to its surface. These currents cease in warm-blooded animals in a few minutes after death; but in cold-blooded animals, such as the frog, they continue for a much longer period.

That there are natural electricities resident in the nerves and muscles to cause these currents, may be shewn by a delicate galvanometer, or by the quadrant electrometer of Sir W. Thomson. By means of this sensitive electrometer, it is found that the surfaces and the ends of nerve (or muscle) fibres are oppositely charged like the two coatings of a Leyden jar. The sheaths of the fibres are supposed to be such bad conductors that they can act as a dielectric, like the glass of the Leyden jar. A charge is given to the outer surface by oxygenation, or in some other way, and an opposite charge is induced by it on the inside. The current that affects the galvanometer arises from the connecting two oppositely charged parts.

But the curious thing is, that the muscle and nerve fibres are *charged*, while they remain *at rest*, and *action* is accompanied with a disappearance or *discharge* of the electricities. This is like the discharge which occurs when the torpedo puts itself in action. Indeed, the discharge of the torpedo may only be 'the unmasked form of what occurs in a masked form in every case of muscular and nervous action.'

As, then, a natural activity of nerve and muscle coincides with natural electric discharges in their tissues, so an artificial activity is induced by artificial discharges. Mere charge or electrification has no effect, so long as it is constant. It is only a *sudden change of charge* (which is really a discharge) that produces an involuntary and artificial activity.

This explains why the passage of a voltaic current is attended with no artificial production of action so long as it is constant. It is just equivalent to a constant charge of the fibres, and, therefore, to a state of rest. Only at the letting on or taking off of this charge do we have a change of state, which is really a discharge; only then do we feel the *shock;* and only then are the fibres excited. This is easily verified by experiment with the galvanic current, either on the living body, or on the bodies of animals recently dead.

The physiological effects of electricity were among the first observed, and had doubtless a good deal to do with the rapid development of the science. The life-like convulsions excited by it in the limbs of dead animals hinted that nerve-force might be nothing but electricity. Many experiments were made on the bodies of oxen, horses, sheep, and such like, soon after death. Executed criminals were even experimented on, and many of the vital actions were alarmingly induced. All this was to find the connection between vital and electrical force. It was clear there was some relation, and it was thought probable that the two forces might be identical.

Experiment has, however, failed to establish any relation between electricity and life, so definite as it has established between electricity and the physical forces of heat, light, chemical, magnetical, and mechanical force. Man would fain find out the secret of life, and the panacea for all his infirmities. But the problem remains, and will remain, unsolved.

HISTORICAL SKETCH.

Magnetism.—All that the ancients knew of magnetism was the property of the loadstone. Even the compass is comparatively modern. We are not sure of its being known in Europe before the end of the twelfth century, though some say the Chinese had it long before. Columbus, on his famous voyage, first noticed the variation of the compass; and about eighty years after (1576), a London instrument-maker discovered the dip. In the beginning of the seventeenth century,

Gilbert published a treatise on magnetism, in which he first applied the term *poles* to the magnet, and he speculated on the nature of the earth's magnetism, and on magnetism generally. The astronomer-royal, Halley, published the first magnetic charts in 1701. Some twenty years after, Graham, the celebrated instrument-maker of London, discovered the daily variation of the compass. Armatures were not used before 1750, when special attention was given to new processes of increasing and preserving magnetism. In 1770, the magnetism of cobalt and bismuth was first observed. About the beginning of this century, Humboldt inaugurated the system of careful observation of the magnetic elements, and in 1835, stations were established throughout Europe for this purpose. In 1831, Captain Ross discovered the north magnetic pole, and Barlow in the same year suggested an electric theory of the earth's magnetism. Colonel Sabine, in 1837, first published an isodynamical chart of the globe, shewing all places of equal magnetic intensity. In 1845, Faraday discovered diamagnetism; and ten years later, Tyndall shewed that a diamagnetic body assumes a polarity similar in action but transverse to that of a magnetic body when under magnetic influence. More recently, Tyndall has discovered that a close relation exists between the optic axes of crystals and the positions in which they set between the poles of a powerful magnet.

Electricity.—The science of electricity dates from 1600, when Gilbert wrote his celebrated treatise. He has given us the earliest speculations on the subject, and bequeathed to us the name electricity itself. In 1672 was constructed, by Otto von Guericke of Magdeburg, the first electrical machine. It was in the humble form of a globe of sulphur, turned by a handle, and rubbed with a cloth in the hand. This Hawksbee replaced, in 1709, by a glass cylinder; and in 1744 a fixed cushion-rubber was first used by Winkler, a Leipsic professor. Accident led to the discovery of the Leyden jar by Musschenbroeck of Leyden, in 1746. While holding in one hand a glass flask filled with water, which he had just charged from a machine, he happened with the other hand to touch a wire which communicated with the water. He received a very violent shock—so violent, that he declared he would not have another for the kingdom of France. In 1747, Franklin explained the action of the Leyden jar, and in 1752 made his well-known kite experiment. The nature of induced electricity occupied the attention of Wilke, Æpinus, and Canton about this time. In 1768, Ramsden first constructed a plate-machine; and in 1780, Nairne brought his cylinder-machine into notice, its value being that it gave either positive or negative electricity. Volta invented the electrophorus in 1775, and in 1782 his well-known condenser. About 1787, Coulomb investigated the laws of electric attraction and repulsion. After this, the science was thrown in the shade by galvanism, until Faraday, in 1837, made some invaluable researches on statical induction, and shewed its action to be universal. More recently, Reiss, Tœpler, and Holtz have paid special attention to the electricity of friction; and the novel induction-machines of the latter two have rekindled the curiosity of experimenters.

Galvanism, Current Induction, &c.—Little idea could Galvani have had that his accidental discovery, in 1786, was the embryo of one of the grandest sciences which the human mind has developed. It was five years ere he published his researches, and then they were thrown as an apple of discord among the philosophers of the time. Volta next year (1792) discarded Galvani's explanation, and gave in place his now equally famous contact theory; while within the same year another professor, Fabroni, of Florence, *suggested* chemical action as having some share in the phenomenon. With the last year of the century (1799) came Volta's crowning evidence of the truth of his reasoning, his zinc and copper pile, which has proved a boon to science and to man. Volta sent the news of his discovery in 1800 to Sir Joseph Banks, in England, and within a few weeks fresh discoveries commenced. Carlisle and Nicholson decomposed water and several of the salts by means of the pile, and every year saw some new application of this remarkable contrivance. Davy traced the origin of the electricity to chemical action, and Wollaston went farther; he even attributed frictional electricity to chemical action, and proved that it can be made to give chemical effects. The voltaic pile was improved by Cruikshank, who gave it the trough form in 1802, which it subsequently assumed in all experiments. In 1806, Davy discussed fully electro-chemical decomposition; and in 1813, by aid of the enormous battery at the Royal Institution, he discovered the wonders of the electric light. Even as early as 1808, Sömmering proposed to effect telegraphic signalling by an electro-chemical process; but it was not till the Dutch philosopher Œrsted discovered, in 1820, the deflection of a magnetic needle by the current, that the basis of our present system was laid. To the same year belong several remarkable ideas. Schweigger followed up the discovery of Œrsted in a few months with his invention of the galvanometer; Ampere proposed the deflections of its needle as a means of telegraphing through a line of wire, but, strange to say, it was put to no practical test for a dozen years more; and, lastly, Ampere produced his electric theory of magnetism, which has been so remarkably fertile in results.

The immortal Faraday now appears on the field, to surpass by his achievements even Davy, his illustrious master. In 1831–1832, he published, in the *Philosophical Magazine*, his researches on electricity, by which he made known his discovery of volta-electric or current induction, and also of magneto-electric induction. His discovery was embodied in the magneto-electric machines of Pixii, Saxton, and Clarke, which appeared in succession between the years 1832 and 1836. About the same time, Faraday established the definite laws of electro-chemical decomposition, and traced the spark, which appears on breaking a long circuit, to the *extra current*, or its own induction. These years were remarkable in the history of electricity, for, in 1833, Ampere's idea of a telegraph was first put to a practical test. Gauss and Weber, at Göttingen, actually established an electric telegraph, about two miles long, between their magnetical observatory and their physical cabinet. The indicator was a reflecting galvanometer, and they made up an alphabet of right and left deflections of the needle. This, however,

was merely looked on as a scientific curiosity, till 1837, when no less than three practical systems were independently tried. In June of that year, Cooke and Wheatstone patented a five-needle telegraph, which was soon after put in action on the Great Western Railway. Their lines were underground insulated wires, and were undoubtedly the first used for general purposes. Cooke had seen in the lectures of Professor Muncke of Heidelberg, one of Baron Schilling's horizontal needle telegraphs, and had been struck by its practical value. In July of 1837, Steinheil, at Munich, established a system of wires, upwards of seven miles in length, stretching them over the houses of the town. He was thus the first to have an air-line. He also first made use of the earth as 'a return wire.' He had three ways of telegraphing—by the deflections of a needle, by the sounding of two bells, and by printing on a strip of paper dots to right and left with positive and negative currents. In October of the same year, Professor Morse of New York exhibited his printing instrument, which we have already described; but it did not come into practical use till 1844. During these years also appeared new forms of galvanic battery, Daniell's in 1837, Grove's in 1839, and Bunsen's in 1843, the importance of the telegraph having given a stimulus to the study of galvanic action. Faraday, in 1840, by a series of testing experiments, seemed to establish the chemical theory of the galvanic current; yet thirty years later, and the balance of opinion has apparently turned in favour of the contact theory, which Sir W. Thomson may be said to have put beyond dispute. The first successful submarine cable was laid in 1851 between Dover and Calais. In 1858, the first Atlantic cable was completed; but it and a second laid in 1865 were not fortunate; that of 1866 was, however, permanently successful. Now there are not a few Atlantic cables, English, American, or French; and there is telegraphic communication (partly submarine) between Europe and India, China, Australia, and the Cape of Good Hope, as there is between Chili and the United States. The perfection of the telephone about 1876, by which sounds, articulate or other, are communicated at a distance by electricity, marked a new application of electric science. The gradual development of magneto-electric or dynamo-machines and electro-magnetic apparatus led in 1881 to an electric tramway at Berlin, followed by one at Portrush in Ireland. Electric boats have also been successfully used; and amongst most recent developments, tricycles lighted and propelled by special tricycle electro-motors have to be mentioned.

With regard to the modern development of electrical science generally, it is remarkable that it should have taken an almost identical shape both in frictional and in current electricity. The machines of Holtz and Tœpler alongside of those of Wilde and Ladd, shew that induction supplies the link between mechanical force and electric energy of whatever form. Of modern contributions to electricity, we cannot here attempt an outline. They are associated with a host of illustrious names, such as Becquerel, De la Rive, Jacobi, Ohm, Harris, Du Moncel, Ruhmkorff, Wheatstone, Bertin, Siemens, Joule, Jenkin, Varley, Edison, Graham Bell, and Sir William Thomson.

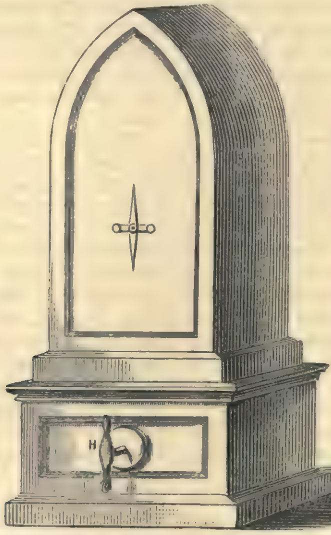


Fig. 45.—Cooke and Wheatstone's Single Needle Instrument.

CHRONOLOGY—HOROLOGY.

THE general relation of events and successive existences to each other we denominate *Time*—a thing of duration, involving the past, the present, and the future. It is evident that for the measurement of time we can have no standard of the same tangible nature with a pound, a yard, or a pint measure. We must have recourse to the space or duration involved in some continued or reiterated *motion*, as to which we have all the proof possible in the nature of the thing, that it requires the same period for its recurrence on one occasion as on every other. The motions of the heavenly bodies are of such a nature, and present the surest standard of reckoning time on a large and comprehensive scale. For periods, however, less in duration than a single day, or day and night, there are no explicit natural standards; hence the utility and necessity of mechanism of human invention, the motions of which, mathematically adjusted and numbered, shall measure and record more brief and arbitrary divisions.

In accordance, therefore, with what is the common practice of mankind in applying such a scale of time to the general routine and business of life, especially in its more civilised condition, we purpose to treat—*first*, of the measurement of time by days, months, years, and cycles, considered with special reference to their respective natural and artificial subdivisions and accumulations; and, *secondly*, of those instruments and machines which have been invented for dividing the leading astronomical unit, or day, into seconds, minutes, and hours. The former of these departments may be termed *Chronology*, or the science of time in general; the latter, *Horology*, or an explanation of the various contrivances which have been devised for marking and measuring its arbitrary subdivisions.

CHRONOLOGY.

Chronology—from *chronos*, time, and *logos*, discourse—is literally the doctrine of time; the science which treats of its various divisions, and of the order and succession of events. The chronologist has thus a threefold duty to perform—namely, to assign a measure to the interval which elapses between successive recurrences of any natural event; to determine certain points or epochs from which to date occurrences, whether preceding or succeeding that epoch; and, lastly, dating from any given epoch, to arrange in due order all facts and phenomena which may be considered of importance. Adopting this course, we shall treat, in the first place, of the division of time into

DAYS AND HOURS.

A day, in the ordinary sense, is one complete alternation of light and darkness, caused by the revolution of the earth on its axis. It takes rather more than a complete revolution of the earth to bring a spot on its surface back into the same position with regard to the sun, because the sun has in the meantime moved forward a little in the sky. The period that thus elapses is a natural or *solar* day. These periods, however, are not of exactly the same length at all seasons of the year, and therefore the mean length is taken as the standard, and is called the *civil* day. It is this civil day, divided into twenty-four equal parts called hours, that our clocks and watches keep. The period of a complete revolution of the earth, which is determined by two successive culminations of a fixed star, is called a sidereal day, and is shorter than the mean day by nearly four seconds (see ASTRONOMY). We have thus three species of day—the sidereal, or that time which elapses between two successive culminations of the same star, and which is now universally adopted by astronomers in their observatories; the solar, natural, or apparent day, being the time that elapses between two consecutive returns of the same terrestrial meridian to the centre of the sun, and which consequently commences at noon; and the civil or mean solar day, which is the mean or average of these meridional returns, and which most modern nations have adopted, placing the commencement and termination at mean midnight.

The succession of day and night would undoubtedly constitute the first great natural period reckoned by the human race—involving, as it does, not only the most familiar and most strikingly contrasted phenomena within the bounds of man's experience, but phenomena peculiarly adapted to the great necessities of his nature—those of vigilance and sleep. Yet the precise point at which the day should be held to begin and terminate, must have been a matter much less easily settled; and accordingly we find, that while amongst ancient nations—the Babylonians, Persians, Syrians, Greeks, and almost all the nations of Asia—the day began at sunrise, and was held to last throughout the whole of the ensuing daylight and darkness—an arrangement better adapted to countries near the tropics than elsewhere, as the sun there rises more nearly about the same time throughout the year—the Jews, Turks, Austrians, and others, with some of the Italians and Germans, have begun their day about sunset; the Arabians theirs at noon, as do astronomers and navigators of all nations; the ancient Egyptians, and most of the modern Europeans and Americans, on the other hand, as well as the modern Chinese, beginning theirs at midnight, which is evidently the most convenient method, since it throws all the waking and active portion of the day under one date.

In the civilised part of the world, it is now customary to divide the day, and reckon the minuter portions of time, by instruments, to be afterwards described, in seconds, sixty of which constitute a minute; in minutes, sixty of which

constitute an hour; and in hours, twenty-four of which constitute a day. Most nations have these instruments marked for only twelve hours, the computation being twofold, like the day itself; but the Italians, Bohemians, and Poles run them on from the first to the twenty-fourth—from one o'clock to twenty-four o'clock. The Chinese, on the other hand, divide the day into twelve hours only, each being, therefore, twice the length of ours.

It is here necessary to observe, that as the earth rotates from west to east, every meridian has its own natural day; and any place east or west of that meridian has a corresponding earlier or later sunrise. The earth, of 360° of longitude, turns in twenty-four hours; consequently every hour is equal to 15°; and every degree equal to four minutes of time. Thus, taking Greenwich as the normal meridian, Alexandria being 30° east, is two hours earlier, or has it twelve o'clock when it is ten at Greenwich; Bengal is 90° east, and it is there twelve at noon when only six in the morning at Greenwich. So New York is 74° west, or 4 hours 56 minutes; and consequently, when noon at Greenwich, it is only four minutes past seven in the morning at New York. As with these large distances, so with every other difference of longitude, however minute; and it is thus that we speak of our clocks being earlier or later than Greenwich time, according as we are situated east or west of that meridian. Ipswich, for example, being east of Greenwich, is about five minutes before, or earlier; Edinburgh, being west, is about twelve and a half minutes behind; and Dublin, being still farther west, is about twenty-five minutes late. Hence the necessity, in these days of rapid transit, of keeping by one uniform standard of time, or at least of having a table of differences for the principal stations throughout the country. In most cases, it would be preferable to have our clocks furnished with two minute-hands—one to indicate Greenwich time, and the other the natural time of the locality.

MONTHS AND WEEKS.

After the day, the next distinct natural measure or division of time marked out by the heavenly bodies in their time-keeping revolutions, is the month. The *lunar month*, or *synodic month*, is the period between two consecutive new or full moons, and is equal to 29 days 12 hours 44 minutes 3 seconds (see ASTRONOMY). The month came ultimately to be disconnected from the lunar and terrestrial revolutions, as will be afterwards more particularly noticed, and civil or *calendar months*, accommodated to the year, were substituted; these also, as well as the names given to them in their annual order, will fall to be noticed while treating of the year itself and its subdivisions.

The subdivision of the month into weeks of seven days is very ancient, but is far from having been universal, as is sometimes assumed. It was probably first instituted as corresponding roughly to the four quarters of the moon. It is found as a civil institution among the Hindus, Assyrians, and Persians from the earliest times; it is only among the Jews that we see a religious signification given to the concluding or seventh day of the period. Whether the Egyptians borrowed it from the Jews, or the Jews from the Egyptians, it is certain that the latter at an early period counted seven periodical days, naming them after the seven planets of the old astronomy. The application of the names of the planets to the days of the week in the order they now stand, originated in this way: It was an astrological notion that each planet in order presided over an hour of the day, the order, according to their distances from the earth, being, on the geocentric system, Saturn, Jupiter, Mars, the sun, Venus, Mercury, the moon. Assuming Saturn to preside over the first hour of Saturday, and assigning to each succeeding hour a planet in order, the 22d hour will fall again to Saturn, the 23d to Jupiter, the 24th to Mars, and the first hour of the next day to the sun; in the same way, the first hour of the following day falls to the moon, and so on. From Alexandria, this seven-days week was imported, together with the names of the individual days, to the Greeks and to the Romans, about the time of Christ. The Greeks had previously divided the civil month into periods of ten days. The Roman month was anciently divided into three periods — *Calends*, *Nones*, and *Ides*. The calends were at the beginning of the month; the ides at the middle of the month, on the 13th or 15th; and the nones (*novem*, nine) were the ninth day before the ides, counting inclusively. From these three terms the days were counted backwards in the following manner: Those days comprised between the calends and the nones were denominated *days before the nones;* those between the nones and ides, *days before the ides;* and those from the ides to the end of the month, *days before the calends*. The Greeks had no calends; hence the Roman phrase, *Græcæ calendæ*, or 'never,' corresponding to the English 'Latter Lammas,' and the Scotch 'Morn come never.'

The Jews, as well as the early Christians, had no special names for the single days, but counted their number from the previous Sabbath, beginning with Sunday, as the first after the Sabbath, and ending with Friday, as the sixth after the previous, or as the eve (*Ereb*) of the next Sabbath. After a very short time, however, Christianity had to fall back again upon the old heathen names, previously introduced in Gaul, Germany, &c. by the heathen Romans. The Sunday, or *dies Solis*, alone was changed in many of the Romanic languages in accordance with the new creed. It was called *Kyriake*, *dies Dominicus* or *Dominica*, the Day of the Lord, a term which in Italian became *Domenica*, in Spanish *Domingo*, and *Dimanche* in French. It is very curious to notice how the names of the five days of the week which followed those named after the sun and moon, became Germanised, as it were, or the names of the originally imported gods translated into those of the Germanic divinities. Thus, the day of Mars became that of Ziu. Mercury became Wodan; and the fourth day was called after the latter, in Dutch, English, and Scandinavian; while in Germany it was simply called the middle of the week—*Mittwoch*. The day of Jupiter became the day of Thor—Thursday, *Donnerstag;* while the *Dies Veneris* was transformed into the day of Freya (Friday). The day of Saturnus, retained under this name in some northern tongues, became a *laugardage*, or bathing-day, in others; while in Upper Germany it remained a Sunday-eve or

Samstag. The Arabs have the seven-days period, and count the individual days instead of naming them, as do the Slavonic nations, and Quakers among ourselves. In England, the Latin names of the days are still retained in legislative and judiciary acts.

YEARS AND SEASONS.

The year, properly so called, or the solar or astronomical year, is that portion of time which elapses while the sun passes through the twelve signs of the zodiac, or rather, while the earth revolves once completely round the sun in its orbit; thus producing an alternation of the seasons (see ASTRONOMY).

The distinction of the seasons would soon be found to depend upon the alternate approach and departure, or elevation and depression, of the sun in the heavens at stated and regularly recurring intervals; but the exact division of time into solar years could not have been effected till astronomy had made some progress; when it would immediately appear, in the endeavours at length made to measure the year by revolutions of the moon, that as an exact number of days, or times of the earth's rotation, is not contained in 'a moon,' or lunar month, so an exact number of moons, or even of days, is not contained in a year, or revolution of the seasons. Such observations as these led to methods of accommodating the one period to the other; or, in other words, to the

ADJUSTMENT OF THE CALENDAR.

Almost all the nations of antiquity originally estimated the year, or the periodical return of summer and winter, by twelve lunations—a period equal to 354 days 8 hours 48 minutes 36 seconds. But the solar year is equal to 365 days 5 hours 48 minutes 49 seconds; or 10 days 21 hours 13 seconds longer than the lunar year, an excess named the *epact;* and, accordingly, the seasons were found rapidly to deviate from the particular months to which they at first corresponded; so that in thirty-four years, the summer months would have become the winter ones, had not this enormous aberration been corrected by the addition or intercalation of an extraordinary month now and then. Thus was the calendar first adjusted, and the solar year estimated to consist of twelve months, comprehending 365 days. But no account was taken of the odd hours until their accumulation forced them into notice; and a nearer approximation to the exact measurement of a year was made about forty-five years before the birth of Christ, when Julius Cæsar, being led by Sosigenes, an astronomer of his time, to believe the error to consist of exactly six hours in the year, ordained that these should be set aside, and accumulated for four years, when of course they would amount to a day of twenty-four hours, to be accordingly added to every fourth year. This was done by doubling or repeating the 24th of February; and, in order to commence aright, he ordained that year, which was called the last 'year of confusion,' to be made up of fifteen months, so as to cover the ninety days which had been then lost. The 'Julian style' and the 'Julian era' were then commenced; and so practically useful and comparatively perfect was this mode of time-reckoning, that it prevailed generally amongst Christian nations, and remained undisturbed till the renewed accumulation of the remaining error of eleven minutes or so had amounted, in 1582 years after the birth of Christ, to ten complete days; the vernal equinox falling on the 11th instead of the 21st of March, as it did at the time of the Council of Nice, 325 years after the birth of Christ.

This shifting of days had caused great disturbances, by unfixing the times of the celebration of Easter, and hence of all the other movable feasts. And accordingly, Pope Gregory XIII. after deep study and calculation, ordained that ten days should be deducted from the year 1582, by calling what, according to the old calendar, would have been reckoned the 5th of October, the 15th of October 1582. The Catholic nations, in general, adopted the *style* ordained by their sovereign pontiff; but the Protestants were then too much inflamed against Catholicism in all its relations, to receive even a purely scientific improvement from such hands. The Lutherans of Germany, Switzerland, and, as already mentioned, of the Low Countries, at length gave way in 1700, when it had become necessary to omit *eleven* instead of ten days. It was not till 1751, and after great inconvenience had been experienced for nearly two centuries, from the difference of the reckoning, that an act was passed (24 Geo. II. 1751) for equalising the style in Great Britain and Ireland with that used in other countries of Europe. It was enacted, in the first place, that eleven days should be omitted after the 2d of September 1752, so that the ensuing day, the 3d, should be called the 14th; and, in order to counteract a certain minute overplus of time, that 'the years 1800, 1900, 2100, 2200, 2300, or any other hundredth year of our Lord which shall happen in time to come, except only every fourth hundredth year of our Lord, whereof the year 2000 shall be the first, shall not be considered as leap-years.' A similar change was about the same time made in Sweden and Tuscany; and Russia and Greece are now the only countries which adhere to the *old style;* an adherence which renders it necessary, when a letter is thence addressed to a person in another country, that the date should be given thus: April $\frac{1}{13}$ or $\frac{\text{June 26}}{\text{July 8}}$; for it will be observed, the year 1800, not being considered by us as a leap-year, has interjected another (or twelfth) day between old and new style.

In the Julian arrangement, the odd months—the first, third, fifth, &c.—were to have thirty-one days, and the even numbers thirty days, except February; but Augustus altered the disposition for that which now holds. The names of the twelve months are strictly Roman; the origin of several of them is obscure.

The commencement of the year, till a comparatively very recent period, was the subject of no general rule. The Athenians commenced it in June, the Macedonians in September, the Romans first in March, and afterwards in January, the Persians on 11th August, the Mexicans on 23d February, the Mohammedans in July, and astronomers at the vernal equinox. Amongst Christians, Christmas-day, the day of the Circumcision, the 1st of January, the day of the Conception, the 15th of March, and Easter-day, have all been used at various times, and by various nations, as the initial

day of the year. Christmas-day was the ecclesiastical beginning of the year, till Pope Gregory XIII. on reforming the calendar, ordered it, in 1582, to begin thenceforward on the 1st of January. In France and England, the same practice commenced about the same time; but in the latter country, it was not till 1752 that legal writs and instruments ceased to consider the 25th of March as the beginning of the year. In Scotland the change was made in 1600. The English plan was found exceedingly inconvenient; for when it was necessary to express a date between the 1st of January, which was the commencement of the historical year, and the 25th of March, which opened the legal one, error and confusion were sure to occur, unless it were given in the following awkward fashion: January 30, 1648–9, or 164$\frac{8}{9}$. Even this was apt to lead to mistakes; and it is perhaps even to this day a matter of doubt with some intelligent persons, whether the execution of Charles I., of which the above is the usual appearance of the date, occurred in the year 1648 or 1649: it in reality occurred in the year which, by our present uniform mode of reckoning, would be called 1649.

The present mode of reckoning time has experienced no interruption in its leading features for many years, except under the French Republic. In September 1793, the French nation having resolved that the foundation of their new system of government should form their era, instead of the birth of Christ, whose religion they had in a great measure shaken off, resolved also that a calendar should be adopted on what was termed philosophical principles. The Convention, therefore, having decreed, on the 24th November 1793, that the common era should be abolished in all civil affairs, and that the new French era should commence from the foundation of the Republic—namely, on the 22d September 1792, on the day of the true autumnal equinox—ordained that each year henceforth should begin at the midnight of the day on which the true autumnal equinox falls. This year they divided into twelve months of thirty days each, to which they gave descriptive names as follows: From the 22d of September to the 21st of October was *Vendémiaire* (Vintage Month); to the 20th November was *Brumaire* (Foggy Month), and so of the rest. In ordinary years there were in this scheme five extra days—namely, from the 17th to the 21st of our September inclusive: these the French called *Jours Complémentaires*, or *Sans-culottides*, and held as festivals; the first being dedicated to Virtue, the second to Genius, the third to Labour, the fourth to Opinion, and the fifth to Rewards. At the end of every four years, forming what they called a Franciade, occurred a leap-year, which gave a sixth complementary day, styled *Le Jour de la Révolution*, and employed in renewing the national oath to live free or die.

The *week*, though not exclusively a Christian or Jewish period of time, they also abjured. The thirty days of the month were divided into three parts, of ten days each, called *Décades;* of which the first nine—called Primidi, Duodi, Tridi, Quartidi, Quintidi, Sextidi, Septidi, Octidi, Nonidi—were working or common days, while the tenth, styled Décadi, was observed as a kind of Sabbath, though not exactly in the Jewish sense of the word. The French, however, in indicating any particular day, either by word or writing, generally mentioned only the number of the day of the month. The Republican Calendar was first used on the 26th of November 1793, and was discontinued on the 31st of December 1805, when the calendar used throughout the rest of Europe was resumed.

CYCLES.

A cycle, from a Greek word signifying *circle*, is a circulating period of time, on the completion of which, certain phenomena return in the same order.

The *Solar Cycle* is a period of twenty-eight years, during which the day of the month, in every succeeding year, falls on a different day of the week, from the first, till the cycle is completed; when the days of the month and week meet as at first, one cycle corresponding to another. By this cycle, which has no relation to the sun's course, we find 'the Dominical letters,' or those letters amongst the first seven in the alphabet—used to represent the days of the week—which point out the days of the month on which the Sundays fall during each year of the cycle. If there were 364 days in the year, the Sundays would happen every year on the same days of the month; if 365 exactly, every seventh year; but because the additional fractional period contained in the year makes an alteration of a day in every fourth year, the cycle extends to four times seven, or twenty-eight years.

The first solar cycle in the Christian era having begun nine years before the commencement of that era, to discover what year of the cycle the year 1872 forms, we must add 9, and divide the sum 1881 by 28, the period of the cycle, and the quotient 67 is the number of solar cycles that have passed during that era, the remaining 5 being the year of the cycle corresponding to 1872.

The *Lunar Cycle*—also called the 'Golden Number,' from its having been written in letters of gold by the Greeks, and the 'Metonic Cycle,' from its having been discovered by Meton, an Athenian astronomer—is a period of nineteen years, at the end of which the phases of the moon occur on the same days of the civil month as in a previous lunar cycle, and within an hour and a half of the same precise moment of time.

The first lunar cycle in the Christian era having begun one year before the commencement of that era, to discover what year of the cycle 1872 forms, we must add 1, and divide the sum 1873 by 19, the period of the cycle, and the quotient 98 is the number of lunar cycles that have passed during that era: the remainder, 11, shewing that 1872 is the eleventh year of the next lunar cycle.

The *Dionysian Period* is a combination of the solar and lunar cycles, forming, by the multiplication of 28 by 19, a period of 532 years, at the expiration of which it is again new moon on the same days of the week and month as before: chronological events are compared and tested by such a calculation.

The *Indiction* may here also be noticed; though, were it not for severing it from the other cycles with which it is connected in the Julian period, it might perhaps more properly appear under the head of epochs and eras. This was a Roman period of fifteen years, the first of which commenced in the year 312 after the birth of Christ.

It was appointed merely for the regulation of certain payments by the subjects of the empire; but it came to be observed by the Greek Church and the Venetian senate, as well as the court of Rome.

The *Julian Period* is a combination of the solar and lunar cycles with the Indiction; the respective periods of 28, 19, and 15 years are multiplied by each other, and the product, 7980 years, is what is called the Julian period, during which there cannot be two years having the same numbers for the three cycles; but at the termination of this period they return in the former order.

The year 1872 is the 6585th of the Julian period; hence it began about 700 years previous to the date vulgarly assigned to the creation of the world, and has been used instead of that era, to obviate the disputes of chronologers, and to reconcile their systems; for all agree as to the year in which the Julian period began.

EPOCHS AND ERAS.

In early times, when there was little mutual intercourse between different countries, it was natural for each nation to take as a starting-point in their annals some event of signal importance in their eyes. This event would form *an epoch*, so named from a Greek word signifying to stop. The enumeration and series of years computed from an epoch is called *an era;* and accordingly of epochs and eras there have been almost as many as there have been of nations. As the eras of ancient nations, however, have become obsolete, it would be useless, as it is here impossible, to enumerate all that we know of, or even any great number of them. But we shall notice a few of the most important in the meantime, reserving the names of all the other principal eras to be afterwards presented together in a tabular form.

The *Era of the Olympiads* is the first on record, and it also became the most celebrated of the ancient methods of computing lengthened periods of time. It took its rise amongst the Greeks 776 years before the birth of Christ. Public games had been instituted at Olympia, a city in Elis, which took place every fourth year, at the recurrence of the full moon after the summer solstice—namely, about the beginning of our July. As this festival made a great impression on the public mind, the people began to reckon by Olympiads, or recurrences of the Olympic games—an Olympiad comprising four years. The computation by Olympiads ceased after the 364th Olympiad, in the 440th year after the birth of Christ, as usually computed. The Greeks latterly adopted a new era, called

The *Era of Seleucus*, or the *Seleucidæ*, sometimes also called the era of Alexandria. This era commenced twelve years after the death of Alexander the Great, at the first conquest (312 B.C.), by Seleucus Nicator, of that part of the east which afterwards formed the immense empire of Syria. This era has also prevailed, and still exists, amongst the people inhabiting the Levant. The Jews reckoned by it till the fifteenth century of the Christian era, when they substituted the supposed era of the Creation, to be afterwards noticed; and they still begin their year according to it, in the month of September or October.

The *Roman Era* was reckoned by the Romans from the epoch of the foundation of their famous city Rome, an epoch taken to correspond to the 753d year before the birth of Christ. The computation of time by the Roman era ceased in the sixth century of the Christian era.

The *Christian Era*, of which we now live in the 1872d year, was not adopted as a mode of time-reckoning immediately after the commencement of Christianity. The era of the Olympiads, the Roman era, the era of Seleucus, and the dates of ecclesiastical councils, and other events then considered of importance, were the common modes of reckoning, and continued partially to be so till a period less remote than many people suppose. Even in Italy, and its celebrated capital, Rome, which became the chief seat of Christianity at a very early period, this era was not used till the sixth century. It was introduced into France in the seventh, but not fully established till the eighth century. In Spain, though occasionally adopted in the eleventh, it was not uniformly used in public instruments till after the middle of the fourteenth century, nor in Portugal till about the year 1415. Now, however, all nations professing Christianity have abandoned other eras, and confined themselves to this; using the Latin words *Anno Domini*, 'the year of our Lord,' or their initial letters A.D. to distinguish it; while, for all dates previous to the generally received epoch of the era, the words *Anno ante Christum*, 'the year before Christ,' their abbreviation A.A.C. or more usually the letters B.C. signifying 'before Christ,' are used. The birth of Christ is now believed to have actually taken place four years earlier than the date fixed for it when this mode of reckoning was introduced.

The *Era of the Hegira* commences at the epoch of the flight of Mohammed from Mecca to Medina, which took place on the 16th day of July 622 A.D. The Mohammedan year is regulated by this event; hence it is used by the Turks, Arabs, and other Mohammedans, comprising a large portion of the modern population of the world.

The *Mundane Era*, or era of the creation of the world, has been the subject of much controversy. As many as 300 different opinions, according to Kennedy, in his *Scriptural Chronology*, have been entertained regarding the period which elapsed between the creation and the incarnation. Some have made it 3616 years; others 6484. From the creation to the deluge, the computation of the Hebrew text makes a lapse of 1656 years; the Samaritan version only 1307; the Septuagint 2262. No ancient chronologist attempted to fix the epoch of the creation: some conceived it impious to do so. In modern times, the impiety has been supposed to lie all the other way. But some enlightened commentators have been bold enough to return to the ancient orthodox idea, so far at least as to maintain that the Scriptural epoch of the creation is indefinite, being merely cursorily alluded to in the words, 'In the beginning God created the heavens and the earth.' Geologists, in general, also adopt this wide interpretation. In the authorised version of the Bible, however, the chronology usually given places the epoch of the creation in the year 4004 B.C. Thus, 1 A.D. is 4004 A.M.; the letters A.M. being used as an abbreviation of *Anno Mundi*, 'year of the world.'

YEARS OF PRINCIPAL ERAS CORRESPONDENT TO 1872.

	Years.	Abbrev.
Era of Creation (Constantinopolitan account)	7381	A.M. Const.
Era of Creation (Alexandrian account)	7364	A.M. Alex.
Era of Creation (Jewish account), 23d Thebet	5632	A.M.
Julian Period	6585	Jul. Per.
Caliyug (Hindu)..Poos or Margaly,	4973	Cal.
Olympiads...7th month 1st year of	663	Olymp.
Era of Rome	2625	A.U.C.
Era of Nabonassar...8th month of	2620	Ær. Nab.
Era of Death of Alexander—3d month,	2197	A. Mort. Alex.
Diocletian, or era of Martyrs—25th Cohiac,	1588	Ær. Diocl.
Hegira.................22d Rabiu II.	1295	A.H.

MISCELLANEOUS PERIODS.

Besides these major periods, we have others of less significance, but still useful to be known, as they are frequently alluded to in works of a historical nature. Thus, a *lustre* (Lat. *lustrum*) is a period of five years; or, more properly, the completion of fifty months, at the end of which term a census was taken of the Roman population. A *generation* is the interval of time elapsed between the birth of a father and the birth of his son, and is generally used in computing considerable periods of time both in sacred and profane history. The interval of a generation is consequently of uncertain length, and depends on the standard of human life, and whether the generations are reckoned by eldest, middle, or youngest sons. Thirty years are usually allowed as the mean length of a generation, or three generations for every hundred years. A *reign* is the interval that elapses between the accession and demise of a monarch or supreme governor, and is a term in frequent use by historians. It is a period, however, of very uncertain duration, and differs in different countries, according as the sovereign may be liable to assassination, deposition, and the like. Dr Hales has, however, shewn that the average standard of reigns is about twenty-three years, reckoning from a series of 454 kings in 10,105 years. A *century* (*centum*, a hundred) is a period of one hundred years, reckoning from the commencement of the first year in any given century; thus the current century is the nineteenth of the Christian era.

TABULAR CHRONOLOGY.

Under this head the leading events, phenomena, or facts recorded in history, are arranged in the order of time in which they have occurred—that is, in chronological order. Referring the reader to the systematic chronologies of Newton, Blair, Playfair, Sir Harris Nicolas, and others, we shall merely remark, that the best mode of tabulating events is that which exhibits the dates in bold characters, and endeavours to arrange in juxtaposition the leading occurrences in the principal countries of the world. By these means, reference is greatly facilitated, and a notion of civil progress more intelligibly conveyed. The language of tabular chronology should always be concise, elliptical rather than expletive—a mere indication rather than an account of the event recorded.

HOROLOGY.

Reference has already been made to the heavenly bodies and their motions as the most primitive and natural, as well as most perfect time-keepers. Our attention here, therefore, must be confined to those artificial machines which have been invented chiefly for the purpose of adding to the convenience of these, by dividing the unit of astronomical time-keeping—namely, the day—into fractional parts, such as hours, minutes, and seconds; there being no such convenient and desirable measurement obvious in nature. The science which explains the methods of so measuring and marking the fractional parts of the day is termed *horology*, from two Greek words, signifying *hour* and *discourse*—a term comprehensive of every time-keeping contrivance, from the simplest sand-glass to the most perfect chronometer. The instruments to which we shall here advert are dials, depending upon the shifting shadow of an object illuminated by the sun; clepsydræ, depending upon the equable flow of a liquid; and clocks and watches,* whose movements are determined by weights and springs.

SUN-DIALS.

Long before the invention of any artificial time-keeper, the interval between sunrise and sunset was really divided, with no little accuracy, even amongst the rudest nations, simply by the shortening, turning, and lengthening of the shadows of trees, rocks, and mountains; and it was this primitive mode of dividing the day which no doubt naturally suggested the first idea of sun-dials. The earliest time-measurer of this description of which we have any historical notice, is the dial of King Ahaz, who lived about 742 years before the birth of Christ. According to Herodotus, the Greeks learned the use of them from the Chaldeans, probably through the Babylonian priest and astronomer Berosus. Mention is made of the hemisphere or dial of this philosopher; and the octagonal Temple of the Winds, which is still standing, shews on each side the lines of a vertical dial, and the centres where the gnomons were placed. In Rome, sun-dials were not known till 293 B.C., when one was erected near the Temple of Quirinus—the rising and setting of the great luminary being the only standards of reckoning previous to this period. The Romans at this time were not aware that a dial made for Rome is not suited to other places. The ancients used hemispherical dial-plates, constructed to shew equal divisions of the time between sunrise and sunset, or *temporary* hours, which varied in length with the seasons. The correct theory and practice of dialling belong to modern times. Vertical plain dials were at one time prevalent, as may be seen

* Although modern machines for measuring time are designated by the general appellation of clocks and watches, they are also distinguished by peculiar names arising from certain modifications in their construction, or from certain particular purposes they are intended to serve. By the term *clock* is understood an instrument which not only shews, but also strikes the hours; a *time-piece* is one which shews the hours without striking them; a *quarter-clock* is one which strikes the quarters as well as the hours; an *astronomical clock* is one which shews sidereal time; a *watch* is a portable or pocket time-piece; a *repeater* is one having a contrivance, by means of which it can be made to repeat the hours; a *chronometer* is a watch of the best kind, or one fit to be employed for astronomical purposes.—*Brande's Dictionary of Science.*

on the fronts and gables of many of our old mansions. At present, the most common construction is the horizontal dial, or that in which the plane of the dial-plate is parallel to the horizon. In this form the style or *gnomon* G, the edge of the shadow of which determines the hour-line, runs in the plane of the meridian—that is, due north and south; while its sloping edge forms an angle with the horizon, or plane of the dial, equal to the latitude of the place in which the instrument is situated, and hence parallel to the earth's axis.

Although a sun-dial may certainly be adjusted so as to point out the time of day within a few minutes, it is needless here to dwell further on the details of an instrument now of little use. The most perfect of sun-dials being only available in sunshine, and not at all through the night—in which, by the way, moon-dials were sometimes used—they were partly superseded, even at a very remote period, by

CLEPSYDRÆ AND SAND-GLASSES.

It has been thought that the regular motion of the dropping of water, and the simpler forms of clepsydræ, or water-clocks, were used for the measurement of time even previous to the invention of sun-dials. They certainly were known in very remote antiquity, and were then used in various parts of Asia and Europe; in China, India, Chaldea, Egypt, Italy, and Greece; into the last of which countries they were introduced by Plato. Julius Cæsar found them even in Britain. The Romans themselves had clepsydræ 100 years before Cæsar's invasion; and it is supposed that the Phœnicians had introduced them into Britain through Cornwall, where they traded for tin. The clepsydra invented by Ctesibius of Alexandria, 250 B.C. consisted of a jar containing water, which slowly escaped by a hole at the bottom, while the oar of a miniature boat on the surface, as it sank with the fall of the water, pointed out the hours, which were marked on the side of the jar. It is even alleged that toothed-wheels were applied to clepsydræ by Ctesibius. Such instruments, however, though brought to great perfection in the ninth and tenth centuries, and indeed still used in India, have never been made to measure time with great accuracy. The principal defect is the unequal dropping of the water, caused by the varying depth or weight of the liquid in the containing vessel, increase or decrease of temperature, and change of barometric pressure. As time-keepers, clepsydræ may therefore be considered as superseded by ordinary clocks and watches.

The running of fine well-dried sand through a tube, or from an orifice in a containing vessel, was another obvious species of regular motion, very analogous to the flowing or dropping of water. Accordingly, sand-glasses, still in use in this and other countries, were of very early invention. We have evidence of their employment in the East about a couple of centuries before the Christian era. Though now used only for rude and trivial purposes—the half-minute glass being still employed on shipboard, and the three-and-a-half minute egg-glass by the housemaid—some centuries ago, in Western Europe, they were the almost universal measurers of brief intervals; and hence the numerous allusions of our poets, and the symbolical representations on our monuments and sculptures.

PLANETARIUMS OR ORRERIES.

It is rather a curious circumstance, that, long before the invention of clocks or watches, artificial machines were constructed, imitative of the motions of the sun, moon, and planets—the natural time-keepers.

Of the planetariums of modern times, the first in England was one made for Lord Orrery, whose name has since been given to such machines. The talented and self-taught astronomer, Ferguson, who was originally a poor Scottish herd-boy, made several orreries, and used chronometers to keep them in motion. But though the accuracy with which wheels and pinions can be made to represent different revolutions is beautifully illustrated by the best of these machines, they can give no just conception of the relative size, distance, or velocity of the planets, or hence of the periods of their revolution. 'As to getting correct notions on this subject (the magnitude and distances of the planets),' says Sir John Herschel, 'by drawing circles on paper, or, still worse, from those very childish toys called orreries, it is out of the question.' A verdict so decided, and from such a source, renders any attempt at description or illustration unmeaning and superfluous.

CLOCKS.

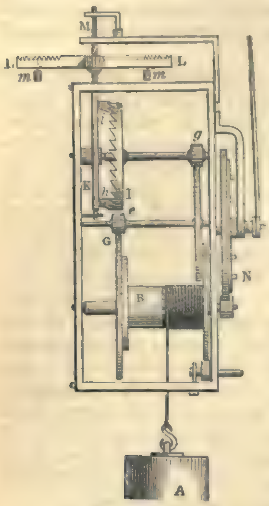
The strong hold which the planetary motions appear to have taken on the minds of our forefathers, as the great antetypes of all true time-keepers, is also curiously manifested in the fact, that even when a more detailed measurement of time became necessary, in the intellectual progress of nations, these motions still continued to be represented, so that the first clock of which we have any perfectly authentic account—that, namely, invented by Wallingford, abbot of St Albans, in 1326—not only shewed the hours, but the apparent motion of the sun, the changes of the moon, the ebb and flow of the tides, &c. This, however, was by no means the first clock ever constructed; instruments with weights, wheels, pinions, and a balance, for the measurement of time, having been long previously known, though by whom invented, appears to be a subject of much controversy. Doubtless, they required more than the intellect of a single mind. Be this as it may, the most ancient clock of which we have any description is that of Henry Vic or De Wyck, a German, erected in the tower of the palace of Charles V. king of France, in 1379; and rude and imperfect as it was, the analogy of modern invention, especially in watches, would lead us to think that it must have been the fruit of several centuries of thought and improvement.

A portrait of this parent of modern time-keepers may be interesting to our readers; and, from its comparative simplicity, will be well adapted as a ground-work for further explanation of the mechanism of clocks and watches in their more complex

and intricate forms. It will, moreover, shew the general mode of construction adopted in the fourteenth century, including the balance with weights, by which the motion was then regulated, instead of as now by a pendulum.

General Movement and Regulation of Clock-work.

Without requiring to enter into any very minute detail of the manner in which motion in a clock or watch is successively communicated from one toothed-wheel G or I, or pinion *e* or *g*, to another, it will be readily understood that the weight A below the clock-work, wound up by a cord on the cylinder B, in its constant tendency to fall to the ground, will cause the cylinder to turn round on its axis; and thus one toothed wheel or pinion will set another in motion, till the movement be communicated to the crown-wheel, escapement-wheel, or wheel of rencounter (I), the teeth of which so act on the two small levers or pallets (*i*, *h*) projecting from, and forming part of, the suspended upright spindle or vertical axis (KM), on which is fixed the regulator or balance (LL), that an alternating or vibratory instead of a circular motion of the balance itself will be the result. The rotatory motion of the wheel-work, in short, will be converted into a vibratory motion by the alternate catching of the levers by the teeth of the crown or escapement wheel, and their alternate escape from them.



De Wyck's Clock.

Were it not for some such check, it is manifest that the weight would go on descending with a rapidly increasing speed till it reached the ground. It is this rapid accelerated motion which begins in a *modern* clock whenever the *pendulum* is taken away. To prevent this rapid unwinding of the clock-work, then, and to adjust it to the more deliberate measurement of time, we have, in De Wyck's clock, the balance *loaded with two weights* (*m*, *m*); and the further these are removed from the axis or spindle (KM), the more heavily will they resist and counteract the escapement of the levers and the rapidity of the rotation of the escapement-wheel, till the clock be brought to go neither too quick nor too slow. The want of a regulation spring, however, must have rendered these machines very imperfect.

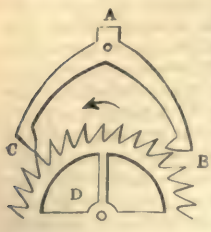
Pendulum and Escapement.

What the balance and the weights attached to it were to clocks of an ancient date, the pendulum is, in general, to modern clocks. The measurement of time being thus regulated by the oscillations of the pendulum, this part of the mechanism of a clock, including the escapement, is of primary interest and importance.

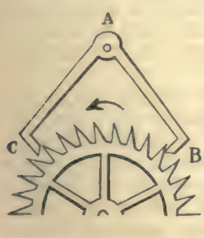
Galileo, the great astronomer, when a student at Pisa, happened to discover, while engaged in the cathedral there—not in meditating on the imposing ceremonial of the Catholic Church, which was then in progress, but in what, to many a good Catholic, would undoubtedly have seemed the vacant, idle, and profane contemplation of the lamps which swung from the roof—that the oscillations of a pendulum, whether great or small, are performed in equal times in the same pendulum—an important fact, the truth of which he tested, not by the beats of his watch (for no such instrument then existed), but by the beats of a natural time-keeper to which we have not yet alluded—namely, the pulse. The law that the time of vibration of a pendulum increases, not as the length, but as the square root of the length—in other words, that a pendulum to beat seconds must be four times the length of one that beats half-seconds—as also the variation of the length with the latitude of the place, are fully described in the number on MATTER AND MOTION. The greatest possible nicety, indeed, is required in the adjustment of the length; for a difference, if in extent amounting to the 1000th part of an inch, would cause an error of about one second a day; therefore, to make a pendulum go slower by one second a day, it must be lengthened by the 1000th part of an inch; and to make it go quicker, it must be shortened in the same proportion.

It does not appear that Galileo ever applied the pendulum to the regulation of time-keepers. Who was the first to do so, is disputed; but as Hüygens, an ingenious Dutchman, about 1657, made a more scientific and efficient application of it than had been done before, he is generally held to be the inventor of the pendulum-clock. Hüygens, in adapting the pendulum to the mechanism previously invented, had little more to do than simply to add a new wheel to the movement, so as to enable him to place the crown-wheel and spindle in a horizontal instead of a perpendicular position, that the lower arm of the balance—then, of course, perpendicular, instead of horizontal, as in De Wyck's clock—might be extended, as it were, downwards, and thus, in fact, be converted into a pendulum. The principle of construction adopted by Hüygens, from the peculiar action of the levers and spindle, required a light pendulum and great arcs of oscillation; and although, to secure isochronous vibration in these large arcs, the ingenious device of constraining the motion in a cycloidal curve was resorted to, yet the consequence was, as has been remarked, that 'Hüygens's clock governed the pendulum, whereas the pendulum ought to govern the clock.' About ten years afterwards, the celebrated Dr Hooke invented an escapement, which enabled a less maintaining power to carry a heavier pendulum. The pendulum, too, making smaller arcs of vibration, was less resisted by the air, and therefore performed its motion with greater regularity. This device is called the *crutch* or *anchor escapement*. It was brought by Hooke before the notice of the Royal Society in 1666; and was practically introduced into the art of clockmaking by Clement, a London clockmaker, in 1680. It is the form still most usually employed in ordinary clocks. It regulates the motion as follows: The pendulum is fixed at A,

and hangs down behind the pallet-wheel (the last of the train of wheel-work), which revolves in the direction of BC, under the action of the weight; B and C are the pallets. When the pendulum swings to the left, AC rises, and a tooth escapes from C, while another falls on the outside of B, and, owing to the form of the pallet B, this latter recoils during the remainder of the swing. The same thing occurs on the pendulum's return; the arm AB rises, a tooth escapes from B, and another falls on the inside of C, and is pushed backwards by it during the remainder of the swing. The revolution of D is thus regularly retarded, one tooth being allowed to escape for every two oscillations—that is, every two seconds—and as the wheel contains 30 teeth, it performs one revolution per minute (the seconds hand is fixed on the extremity of the axle of this wheel). During a portion of each contact between the pallets and teeth, the onward pressure of the wheel gives an additional impetus to the pendulum, so as to counteract the retarding effects of the resistance of the air and friction, which would otherwise bring it to a stand.



The only defect of this escapement is the recoil, and various modifications have been devised to obviate this. The first and most successful was made by George Graham, an English watchmaker in the beginning of the 18th century, and his improved form is called the *dead 'scapement* or *dead-beat escapement*. Here the outer surface of B and inner of C are arcs of circles, whose centre is A, and a little consideration will shew that there can be no recoil. This escapement is adopted in time-keepers when great accuracy is required. Other inventions, as the *detached escapement*, the *pin-wheel escapement* in various forms, and the *gravity escapement* (described below), though very efficient, have not come into general use.

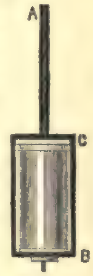


In the great clock in the new Houses of Parliament at Westminster, the pendulum is upwards of 13 feet long, to beat 2 seconds, and its bob weighs 6 cwts. The motion is kept up by a *remontoir* or *gravity escapement*. On each side of the pendulum-rod a small metallic hammer is hung upon a peg. 'The swinging of the pendulum first draws out a little bolt, that stopped the turning of a wheel; the wheel then goes round, under the influence of the weight, lifting one of the little hammers as it does so, until it is caught by another bolt. The hammer-head next falls by its own gravity, and strikes the pendulum-rod just as it is in the act of descending, communicating the force of its blow to quicken the movement; the same thing is afterwards repeated on the opposite side of the vibration, and then again on the same side; so going on alternately.' The push thus given is evidently unvarying. The wheel has three stops and cogs on it, and goes once round in three beats of the pendulum, or in six seconds. With this contrivance 'it is found that all the teeth of the several wheels may be rough, just as turned out from the casting, and the clock will nevertheless keep better time than it would have done with the most perfectly finished teeth under other arrangements.'

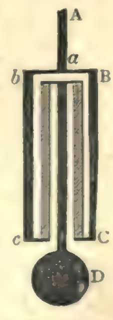
The gradual perfection of the clock required also improvements in the pendulum. No simple pendulum, however, can be depended on for an accurate time-keeper, for the isochronism of vibration of the pendulum depends on its being always the same length; now a cord contracts or expands with changes in the moisture of the atmosphere, and a rod with cold or heat. To overcome these defects in the pendulum, compensating pendulums were invented, of which Graham's *mercurial compensation pendulum*, invented in 1715, and Harrison's *gridiron pendulum*, in 1726, are the two principal forms.

Compensation Pendulums.

In the mercurial pendulum represented in the fig., the rod A, and the framework CB, are of steel. Inside the framework is placed a cylindrical glass jar, nearly full of mercury, which can be raised or depressed by turning a nut at B. By increase of temperature, the steel portion AB is lengthened by an amount proportional to its length, its coefficient of linear dilatation, and the change of temperature, conjointly—and thus the jar of mercury is removed from the axis of suspension. But neglecting the expansion of the glass, which is very small, the mercury rises in the jar by an amount proportional to its bulk, its coefficient of cubical dilatation, and the change of temperature, conjointly. Now, by increasing or diminishing the quantity of mercury, it is obvious that we may so adjust the instrument that the length of the equivalent simple pendulum shall be unaltered by the change of temperature. The screw at B has nothing to do with the *compensation;* its use is to adjust the length of the pendulum so that it shall vibrate in one second.



The construction of the *gridiron* pendulum will be easily understood from the cut. The black bars are steel, the shaded ones are brass, copper, or some substance whose coefficient of linear dilatation is more than double that of steel. It is obvious from the figure that the horizontal bars are merely connectors, and that their expansion has nothing to do with the vibration of the pendulum, so they may be made of any substance. It is easily seen that an increase of temperature lowers the bob by expanding the steel rods, whose effective length consists of the sum of the lengths of A*a*, BC, and the steel bar to which the bob is attached; while it raises the bob by expanding the brass bars, whose effective length is that of one of them only; the other, as well as the steel rod *bc*, being added to the instrument for the sake of symmetry, strength, and stiffness only. If the effective lengths of steel and brass be inversely as their respective dilatation coefficients, the position of the bob is unaltered by temperature; and therefore the pendulum will vibrate in the same



period as before heating. Practically, it is found that a strip of dry fir-wood, carefully varnished, to prevent the absorption of moisture, is very little affected by change of temperature; and, in many excellent clocks, this is used as a very effective substitute for the more elaborate forms just described.

Other Improvements.

While improvements were effecting in the escapement and pendulum of clocks, the ingenuity of artists was not confined to these alone. Till the beginning of the sixteenth century, clocks were of great bulk, and only fit for turrets or large buildings; and although after this period they were made small enough to be introduced into apartments, there could be no such thing as a really portable clock, far less a watch, till weights and pendulums were got rid of altogether. The substitution of a mainspring for a weight, therefore, constituted a great era in horology, or the science of time-keeping; and this took place about the middle of the sixteenth century, and was shortly afterwards followed by the invention of the *fusee*, a very necessary appendage to the mainspring. But as these inventions, together with the balance-spring, rather constitute peculiar features of the watch than of the clock, we shall reserve the explanation of these ingenious pieces of mechanism till we come to treat of watches. Meantime, there is another part of the works which requires to be here noticed—namely, the

Mechanism for Striking the Hours.

It is not known when the alarm or when the striking-mechanism of the clock was first applied. The alarm was adopted for the use of the Romish priesthood, to arouse them to their morning devotions. The first striking-clock probably announced the hour by a single blow, as they still do, to avoid noise, in most of the Scottish churches. In De Wyck's clock, the wheel N, with its projecting pins, served to discharge the striking part, which it has not been thought necessary to illustrate. Like other old clocks, it locked against an interrupted hoop, fixed on what was called the *hoop-wheel;* and the eleven notches on the edge of the plate-wheel determined the hours, or particular number of blows which the hammer should give. During the seventeenth century there existed a great taste for striking-clocks, and hence a great variety of them. Several of Tompion's clocks not only struck the quarters on eight bells, but also the hour after each quarter; at twelve o'clock, 44 blows were struck; and between twelve and one, no less than 113! Many struck the hour twice, like that of St Clement Danes, in the Strand, London, first on a large bell, and then on a small one. Others, again, were invented so as to tell the hours with the least possible noise.

The striking part of a clock is rather a peculiar and intricate piece of mechanism. In ordinary clocks, the impelling power is a weight similar to that which moves the time-measuring mechanism itself; but the pressure of this weight on the striking-machinery is only permitted to come into play at stated periods in course of the workings of the time-keeping apparatus—namely, at the completion of every hour; when the minute-wheel, which revolves once in an hour, and carries the minute-hand of the clock along with it, brings it into action by the temporary release of a catch or detent, permitting the weight wound up on the cylinder of the striking-apparatus to run down for a little, in doing which, the hammer is forced into action, so as to strike the bell. Whether the strokes shall be one or many, is determined principally by two pieces of mechanism, one called a *snail*, from its form or outline, with twelve steps, and the other a *rack*, with twelve teeth; but the intricate action of the whole it would be in vain here to attempt to explain. Suffice it to say, that the time during which the striking-weight is *allowed* to descend, varies according to the turning of the twelve steps of the snail on its axis, and the position of the twelve teeth of the rack, at different hours of the day; being sometimes only long enough to permit one blow to be given by the hammer on the bell, and at another time long enough for twelve such blows.

The lifting piece of the rack-hook, in some clocks, may be raised by pulling a string attached to a small additional piece of mechanism, and thus the clock is made to repeat the hour last struck at any time required—an addition useful through the night, or to the blind. The modes, however, by which clocks as well as watches have been made repeaters, have been very various. Repeating-clocks were first invented by Barlow, an English clergyman, and executed by Tompion in 1676. Some have been made to repeat both hours and quarters at any time, and to indicate the time by blows which might be felt but not heard.

The bells connected with clocks, especially those of churches and other public buildings, are often worthy of notice, either on account of their gigantic size, or on account of the arrangements by which they are made to perform a variety of musical chimes. The largest bell in the world is the 'Monarch' of Moscow, which is above 21 feet in diameter and in height, and weighs 193 tons. It was cast in 1734, but fell down during a fire in 1737—was injured, and remained sunk in the earth till 1837, when it was raised, and now forms the dome of a chapel, made by excavating the space below it. Another bell in Moscow weighs 80 tons. The great bell of Peking, 13 feet in diameter, and 14 feet high, weighs 53½ tons; those of Olmütz, Rouen, and Vienna weigh nearly 18 tons. The most noted bells in Britain are—'Great Peter,' placed in York Minster in 1845, whose weight is nearly 11 tons; 'Great Tom' of Lincoln, 5½ tons; and the great bell of St Paul's, 5 tons. The bell cast for the New Palace of Westminster, but afterwards cracked, weighed 14 tons; that of the Roman Catholic Cathedral of Montreal, 13½ tons. The metal of which bells are made is generally an alloy of 80 parts copper and 20 tin.

The illumination of clocks was a favourite idea in the seventeenth and eighteenth centuries, and is equally useful in a public way as the striking of hours or the ringing of bells. It was only during the current century, however, that any plan was adopted for public clocks; the first notion being to light them from without, by reflecting the light of a common lamp or gas-jet on their dials. This simple method is still employed, but is vastly inferior to the employment of a translucent dial, with a strongly reflected light from behind.

Curious Clocks.

Various and ingenious, as well as often highly curious, have been the forms and purposes displayed in the construction of clocks, even from their earlier epochs down to the present day. We have already instanced some of an ancient date which pointed out the motions of the sun and moon, the ebb and flow of the tides, &c. Others of a more fanciful description followed. The famous astronomical clock of Strasburg, completed by Isaac Habrecht about the end of the sixteenth century, deserves a prominent place in our catalogue. It was renovated by a M. Schwitgue in 1842, and probably suffered more or less injury in the bombardment of 1870; but its original movements are thus described in Morrison's *Itinerary:* 'Before the clock stands a globe on the ground, shewing the motions of the heavens, stars, and planets. The heavens are carried about by the first mover in twenty-four hours. Saturn, by his proper motion, is carried about in thirty years; Jupiter, in twelve; Mars, in two; the Sun, Mercury, and Venus, in one year; and the Moon in one month. In the clock itself there are two tables on the right and left hand, shewing the eclipses of the sun and moon from the year 1573 to the year 1624. The third table, in the middle, is divided into three parts. In the first part, the statues of Apollo and Diana shew the course of the year, and the day thereof, being carried about in one year; the second part shews the year of our Lord, and the equinoctial days, the hours of each day, the minutes of each hour, Easter-day, and all other feasts, and the Dominical letter; and the third part hath the geographical description of all Germany, and particularly of Strasburg, and the names of the inventor and all the workmen. In the middle frame of the clock is an astrolabe, shewing the sign in which each planet is every day; and there are the statues of the seven planets upon a circular plate of iron; so that every day the planet that rules the day comes forth, the rest being hid within the frames, till they come out, of course, at their day—as the sun upon Sunday; and so for all the week. There is also a terrestrial globe, which shews the quarter, the half-hour, and the minutes. There is also the figure of a human skull, and the statues of two boys, whereof one turns the hour-glass, when the clock hath struck, and the other puts forth the rod in his hand at each stroke of the clock. Moreover, there are the statues of Spring, Summer, Autumn, and Winter, and many observations of the moon. In the upper part of the clock are four old men's statues, which strike the quarters of the hour. The statue of Death comes out at each quarter to strike, but is driven back by the statue of Christ, with a spear in his hand, for three quarters; but in the fourth quarter that of Christ goes back, and that of Death strikes the hour with a bone in his hand, and then the chimes sound. On the top of the clock is an image of a cock, which twice in the day crows aloud, and claps his wings. Besides, this clock is decked with many rare pictures; and being on the inside of the church, carries another frame to the outside of the walls, whereon the hours of the sun, the courses of the moon, the length of the day, and such other things, are set out with great art.'

Other ancient clocks displayed processions of saints, with obeisance to the Virgin and Child, &c.; and scarcely a town of any importance was without some curiosity of this sort peculiar to itself. Many curious specimens were invented in the seventeenth century; amongst which were a variety measuring time, or at least moved, by balls running down inclined planes, swallowed up by, and traversing the bodies of, brazen serpents, or descending in metallic grooves, to be again thrown up by Archimedean screws: some were made to go by their own weight, descending inclined planes, and thus avoiding the casualties to which mainsprings and weight-lines are liable; others, by means of springs, were even made to ascend such planes. One clock was simply and ingeniously hung like a lamp from the ceiling, and was kept going by its own descent, the winding up consisting merely in pushing it again towards the ceiling. In another, the dial formed the brim of a plate, filled with water, in which swam a tortoise, turning marvellously with the hour, and ever pointing towards it—by magnetic attraction, as every one would now readily conceive; and this favourite idea was varied by many other simple contrivances.

The improvements above described in the escapement and the pendulum bring the mechanical perfection of the clock, as a time-keeping instrument, to the point which it has attained at the present day. But the art of horology would be incomplete unless there were some standard, independent of individual mechanical contrivances, to which all may be referred, and by which the errors of each—which must exist in the most perfect human contrivances—may be corrected. The movements of the heavenly bodies are still, as of old, the only standard for a general measurement of time, affording as they do marks of unvarying certainty. These marks or signals can, however, only be accurately read by persons furnished with the proper apparatus, and instructed sufficiently in its use. This is done in observatories, and there are in most parts of this country now sufficient opportunities of setting clocks by a communication more or less direct with these establishments. For the more ready transmission of correct time to the public, there is at Greenwich Observatory, as well as some others, a ball which is dropped by means of electricity precisely at one o'clock. Within the last few years, however, there has been invented a most ingenious device by which public clocks in a town can be kept at every instant in perfect agreement with the mean-time clock in the observatory. This is effected by an electric connection, and a modification of Bain's electric pendulum, invented by Mr R. L. Jones of Chester.

In the electric clock or pendulum invented by Mr Bain, about 1844, electricity, or rather electro-magnetism, was the moving power. The clock consisted of the pendulum and two or three small wheels connecting its oscillations with the motion of the hands. There were neither weights nor spring, and nothing to wind up. The bob of the pendulum, in oscillating, was made alternately to break and remake an electric circuit which converted it, from time to time, into a temporary magnet; and thus the attraction and repulsion of two permanent magnets, one on each side, kept up its motion. Clocks, however, moved directly by electricity were found unsatisfactory; and a modification was introduced about 1851, in which the

electricity, instead of maintaining the pendulum-motion immediately, draws up a weight which discharges that function, on the principle of the gravity escapement.

But more important is the device of Mr Jones mentioned above. It consists in making a standard clock of the usual construction to regulate the flow of a galvanic current, and thus control the action of any number of secondary clocks, also of the ordinary construction. The pendulums are not intrusted solely to the stimulus of the electricity, but are moved by their own weights, as in ordinary clocks, so that if the electricity ceased to be sent to them, they would go on without it. It might be supposed that a confusion of the two forces, electricity and gravity, would ensue; such, however, is not the case. While the motion of the clock is intrusted to its own weight, the pendulum submits docilely to the controlling action of the electricity; and thus a secondary clock of little value may be invested with all the perfection of the most costly observatory clock. The success of Jones's pendulum has been severely tested in the arrangement employed by Professor Smyth for firing the one o'clock time-gun at Edinburgh. A clock in the Castle of Edinburgh is made to liberate the trigger of the gun exactly at one o'clock. This clock is regulated on Jones's principle, by a clock at the Observatory on the Calton Hill, nearly a mile distant. The Observatory clock, by means of electricity, sets off a time-ball on a neighbouring monument at the same instant. The fall of the ball, and the flash of the gun, though occasioned each by its own clock, are perfectly simultaneous.

Miscellaneous Clock-work.

The applications of clock-work to other purposes than that of measuring time are numerous and important. In all of them, however, the principle is the same—namely, the indication of space, or, what is equivalent, the indication of time or number by mechanical motion. All our *meters*, by which the discharge of gases and liquids is now measured, are but combinations of clock-work; as are also those numerous inventions for *registering* events connected with atmospheric temperature, rise and fall of barometric pressure, direction and force of wind, vigilance of sentinels, and the like.

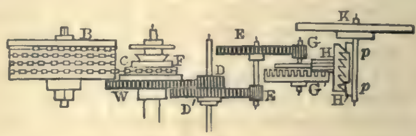
Thus, by a properly constructed *anemometer* (literally, wind-measurer), not only may the force and direction of the wind be ascertained at any given moment, but the instrument may be made to trace or register the direction from which, and the force with which, the aërial current has swept during every minute of the day—all that is necessary being, to place under the tracing-pencils a clean sheet of paper every twenty-four hours. A curious time-keeping method of insuring the presence and attention of night-watchmen has been successfully tried. It consists of a clock with pins projecting round the dial, which can only be pushed inwards at a certain interval, when the watchman's presence and attention are required to unlock the case, and do so; otherwise, his neglect, and the exact quarter of an hour at which he was absent, are shewn by the *tell-tale*.

Closely allied to these varieties of clock-work, but evincing a greater degree of scientific skill, are the various machines which have from time to time been invented to lessen the drudgery of long and continuous calculation. The most ambitious of those contrivances were those projected by the late Mr Babbage, but none of them, we believe, were so far perfected as to do actual work. The Arithmometer of M. Thomas of Colmar executes all ordinary arithmetical operations, and is in actual use. Opinions, however, are divided as to possible advantages derivable from such machines. In the *Journal of the Institute of Actuaries* for July 1871, two writers uphold their utility on the ground of actual experience; another, after pointing out their drawbacks, and the limits of their use, concludes that 'arithmeticians have not much to expect from the aid of calculating machines. A few tables, otherwise easily made, comprise the whole extent of our expected benefits.'

WATCHES.

Clocks and watches are certainly amongst the most perfect, as, in the civilised world, they are the most indispensable machines ever produced by human ingenuity. 'To become a good watch-maker,' says Berthoud, 'it is necessary to be an arithmetician, in order to find the revolutions of each wheel; a geometrician, to determine the curve of the teeth; a mechanician, to find the forces that must be applied; and an artist, to be able to put into execution the principles and rules which these sciences prescribe. He must know how fluids resist bodies in motion; the effects of heat and cold on different metals; and, in addition to these acquirements, he must be endowed by nature with a happy genius.' No one who has not closely attended to the matter, can conceive the difficulty which has been experienced even in dividing circles for the wheels of a watch into the requisite number of rigorously equal parts, and in 'pitching' them in, or adjusting them one with another. All the resources of art shewn by Ramsden, Troughton, and other eminent mathematical instrument-makers, have been here called into requisition. And as to the delicacy of touch and adjustment necessary in the mere regulation of the mechanism, after being thus accurately made and 'pitched in,' some slight idea may be formed from the fact, which we give in the words of Mr Thomson, that 'a second (a mere pulsation) is divided into four or five parts, marked by the vibrations of a watch-balance, and each of these divisions is frequently required to be lessened an exact 2880th part of its momentary duration!'

Before entering upon a description of the various parts, we here present the general arrangement of the wheel-work of a common vertical watch—the frame-plates being omitted, and the dial being supposed to be turned downwards. B is the *barrel* or drum, containing the spring which produces the motion. F is the *fusee*, connected with



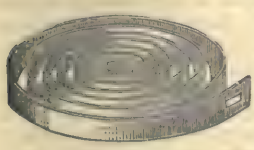
the barrel by the chain *c*. W is the *fusee-wheel*, called also the first or great wheel, which turns with the fusee, and works into the pinion D, called

the *centre-wheel pinion:* this centre pinion, with the centre wheel or second wheel D′, turns once in an hour. The centre wheel D′ works into the *third-wheel pinion* E; and on the same arbor is E′, the *third wheel,* which gives motion to the fourth or *centrate-wheel pinion* G, and along with it the centrate-wheel G′. The teeth of this wheel are placed at right angles to its plane, and act on the pinion H, called the *balance-wheel pinion;* H′ being the balance-wheel, or *scape*-wheel, or crown-wheel, attached to the same arbor. The balance-wheel acts on the two *pallets, p, p,* attached to the *verge* or arbor of the *balance* K; and these being placed at a distance from each other, equal to the diameter of the balance-wheel, and in different places, receive alternately from the scape-wheel an impetus in opposite directions, which keeps up the vibratory motion of the balance. Such is the general arrangement of the powers and motions; we shall now proceed to the analysis.

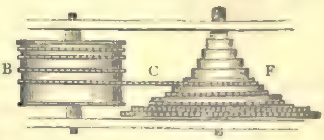
Mainspring and Fusee.

The invention of the mainspring, in place of the weight, was the first pre-requisite to the formation of the watch. But although the mainspring was applied as the maintaining power to time-pieces of a very imperfect description, called watches, about the middle of the sixteenth century, and although the balance had, in such instruments as these, assumed its present form of a vibrating ring, with the greatest weight of course accumulated round a circumference, it was not until the spiral hair-spring was applied to the balance, some time after the invention of the pendulum, as a substitute in clocks for the balance itself, that a comparatively useless machine was converted into a time-measurer nearly as accurate, even in its ordinary form, as the pendulum-clock. Though the invention of the balance-spring, however, was comparatively an early improvement, and the greatest the watch has ever received, we must pass it over in the meantime, till we briefly describe those parts of the mechanism which first rendered the existence of the watch possible at all.

The *mainspring* consists of a coil of thin elastic steel ribbon, inclosed in a miniature barrel or 'drum,' to the inner side of which the outer end of the coil is fixed, while the inner is fixed to an axis at the centre of the drum, round which it may be wound or twisted, so as, by its elasticity and recoil, to cause the drum to make as many revolutions as it makes turns itself while it unwinds. Here, then, we have the main power which sets the whole mechanism of the watch in motion. But it is evident that this power, if thus at once applied to the wheels, would cause them to move with less and less rapidity as it became uncoiled, and as its springing power of course became exhausted; so that unless the wheels were so constructed that only the middle turns were required to be in action, and not those in which it is at its greatest or its least power, a force sufficiently equal even for ordinary purposes could not be thus obtained. French spring-clocks, strange to say, are still, in general, made on this defective principle; but English watches and spring-clocks are supplied with a 'fusee,' which corrects the inequalities of the mainspring with a simplicity only equalled by its ingenuity.



The *fusee,* F, is a cone with a spiral groove, attached to the side of the first wheel of the watch,

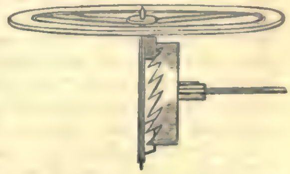


and connected with the barrel or drum B, containing the mainspring, by a chain C, hooked, at its ends, to both.

In winding a watch, the key is placed on the axis of the fusee, and the chain is wound off the barrel on to the cone of the fusee. When fully so wound, the spring is at its greatest power of recoil; but the chain being then round the smallest part of the cone, the influence of the spring on the wheels is at its least amount; while, just as the power of the spring relaxes and diminishes, the cone enlarges, and its lever-influence hence increases. The fusee, in short, is a variable lever, worked by the mainspring, with more purchase when it has less power, and with less purchase when it has more power. It is a very beautiful contrivance, completely answering the intended purpose, when properly made. By means of a spring contained in the interior of the fusee-wheel, the watch is maintained in motion, while the fusee itself is turned by the watch-key in winding up the mainspring. This is called the *going fusee.* When the watch or spring-clock has no fusee at all—and in very flat watches no fusee *can* be introduced—the barrel is immediately attached to the first wheel. In every case, however, the power of the spring is conveyed through the wheels, by nearly the same arrangement in all watches and clocks, to

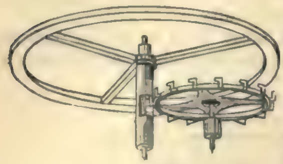
The Escapement.

On the peculiar construction of this part of the mechanism, so as best to keep up the vibrations of the balance, the superiority of one watch over another principally depends. The *vertical* escapement, represented in the adjoining figure, is liable, though in a less degree, to the same objection as the old crown-wheel and the crutch or anchor escapements in clocks. There is a recoil of the scape-wheel after one of its teeth has been stopped by a pallet, which interferes more or less with the accuracy and uniformity of the motion of the train.

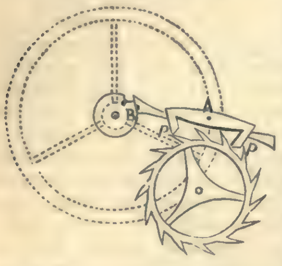


Almost immediately after the invention of the balance-spring, attempts began to be made to introduce an escapement which would produce greater accuracy than the vertical escapement. Hooke, Hüygens, Hautefeuille, and Tompion introduced new principles, each of which has since been successfully applied, though they all, from imperfect execution, failed at the time. The first

real improvement was made by George Graham, the inventor of the dead escapement in clocks. This is called the horizontal escapement; it was introduced in the beginning of the last century, and it is still the escapement used



in most foreign watches. The impulse is given to a hollow cut in the cylindrical axis of the balance, by teeth of a peculiar form projecting from a horizontal crown-wheel. Other forms of escapement in high estimation are the lever escapement, originally invented by Berthoud, improved by Mudge; the duplex escapement, the principle invented by Hooke, the construction perfected by Tyrer; and the detached escapement of Berthoud, improved by Arnold and Earnshaw. The last-mentioned is that which is employed in marine chronometers and in pocket-chronometers, as watches made in all respects like chronometers are called. The lever escapement is that which is used in most English watches. In it the scape-wheel and pallets are exactly the same as in the dead escapement in clocks. The pallets, *p*, *p*, are set on a lever which turns on their arbor, A; and there is a pin, B, in a small disc on the verge or arbor of the balance, which works into a notch at the end of



the lever. The pin and notch are so adjusted, that when a tooth of the scape-wheel has got free, the pin slips out of the notch, and the balance is detached from the lever during the remainder of its swing; whence the name *detached* lever escapement, originally applied to this arrangement. On the balance returning, the pin again enters the notch, moving the lever just enough to send the tooth next in order to escape from the dead face of the pallet on to the impulse face; then the scape-wheel acts upon the lever and balance; the tooth escapes, and another drops upon the dead face of the pallet, the pin at the same time passing out of the notch in the other direction, leaving the balance again free. This arrangement is found to give great accuracy and steadiness of performance. To prevent the teeth from slipping away while the balance is free, the faces of the pallets are slightly undercut, and this makes them secure while at rest; moreover, there is a pin on the lever which moves through a notch on the balance disc, while the pin, B, moves through the notch in the lever, which is so adjusted as to guard against the lever moving and the teeth escaping, while the balance is free.

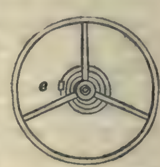
Balance and Balance-spring.

These are the only other parts of the mechanism of the watch of which it is necessary here to treat.

The balance, as may be seen from the representations of it in connection with the different escapements just noticed, is a wheel finely poised on its axis; the pivot-holes in which it turns being frequently—in chronometers and clocks, as well as in watches—jewelled, or made of small rubies, diamonds, &c.; as those of other of the wheels also are, for the sake of durability. The natural effect of an impulse given to such a wheel would be a complete rotation on its axis. This, however, as we have already seen, is convertible, by various escapements, into a vibratory motion. But as in clocks the pendulum was found to be a most invaluable adjunct, absorbing, as it were, in its own more or less extended oscillation, every inequality in the rotation of the wheel-work, or the vibration of the balance, something of precisely the same nature for watch-escapements was the great desideratum, when the balance-spring or hair-spring was invented; and, from this analogy, it even acquired, improperly, the name of the pendulum-spring.*

Simple and obvious as the suggestion of the regulative influence of a spring, applied to the vibrating mechanism of the watch-balance, in place of either weight or pendulum, may now appear—especially after the idea of the mainspring, as a substitute for the maintaining weight, had been suggested—this has been held to be a crowning invention in the mechanism of the watch; and the honour of its first suggestion has been claimed by no less than three very eminent men—by Dr Hooke; by Abbé Hautefeuille, a Frenchman; and by Hüygens, the Dutch astronomer. It was ultimately proved, that although Hüygens had applied for a patent at Paris in 1674, Hautefeuille had done so several years before; while Hooke had made a similar application in England in 1658. To Hooke, therefore, must be attributed the first idea of the balance-spring.

In its application to the balance of a watch, one of the extremities (*e*) of the spring is fastened to a point independent of the balance, while the other is attached near its axis. When the balance is at rest, the spring is inclined neither way, this position being called the point of rest; but when the impulse is given to the balance



by the crown-wheel of the escapement, it is clear that now a rotatory motion of the balance cannot take place, even though there should be nothing in the form of the escapement to prevent it; the balance will now only move round so far as the impulse given is able to overcome the elastic resistance of the spring; and when that resistance becomes equal to the impulse given, the balance will stop for a moment, and then be driven back by the elastic recoil of the spring, continuing thus to vibrate so long as the impulse is repeated or the watch is in motion.

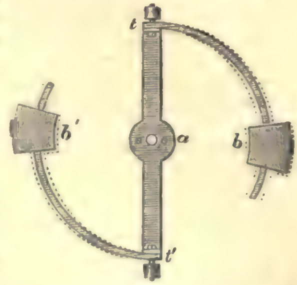
The recoil of the spring is sufficient to drive back the balance to a distance nearly double the length of its first motion; this is therefore called the long arc of vibration. But when the motion of the balance is free, with a certain length of spring, the *long* arc of vibration is made in less time than

* This little instrument, the hair-spring, is no less remarkable for the extreme delicacy of its construction, than for the great value which it shews the possibility of giving to a piece of steel, of exceedingly small and insignificant appearance, by manual labour. Four thousand hair-springs scarcely weigh more than a single ounce, but cost often more than £1000!

the short one, to which the impulse is given: with a spring of greater length this principle is reversed; whence it was concluded by Le Roy and Berthoud, that equality of time, or *isochronism*, in unequal vibrations, could be more easily obtained by lengthening the spring than by tapering it. In principle, too, the stronger and shorter the spring, the quicker will be its vibrations. Thus effects of an extremely varied description can be produced on the motions of a watch by the slightest difference of length and taper in a hair-spring. And it is thus that the correctness of the time-keeping is essentially dependent on the principle adopted in the formation of this apparently most insignificant little appendage. So much is this the case, that if the hair-spring be isochronal in a free or detached escapement, the time shewn will be the same, notwithstanding changes in the motion of the wheels, or even in the power of the mainspring. In England, where time-keepers have been brought to their greatest perfection, it is considered that isochronism is most easily attainable by using the cylindrical helical spring, which is applied to all marine chronometers.

Compensation.

In watches, even more than in clocks, variations of temperature, unless provided for, produce variations in the rate of going, the increase or diminution of the temperature affecting to some extent the moment of inertia of the balance, and to a great extent the elastic force of the balance-spring. A rise in the temperature makes the balance expand, and therefore augments its moment of inertia; it adds to the length of the spring, and thereby diminishes its elasticity, the elastic force of a spring varying inversely as the length; and the time of vibration of the balance, which depends upon the moment of inertia directly, and upon the elastic force of the spring inversely, is increased—the watch, that is, goes more slowly—in consequence both of the increase of the inertia and of the diminution of the elastic force of the spring. A fall in the temperature is attended by opposite results, the watch going more rapidly than before. A watch without a compensated balance would vary very much more than a clock without a compensation pendulum, but that being usually carried in the waistcoat pocket, it is kept at a pretty uniform temperature. To invent a satisfactory compensation, was at one time the great problem for watchmakers. The compensation can obviously be made in either of two ways—by an expedient for shortening the effective length of the balance-spring as the temperature rises, so as to increase the elastic force of the spring; or by an expedient for diminishing the moment of inertia of the balance as the temperature rises, so as to correspond to the diminution of the force of the spring. The first method was that made use of by John Harrison, who first succeeded in making a chronometer capable of measuring time accurately in different temperatures; but an adaptation of the other method, invented by Earnshaw, is that which is always employed now: $t\ a\ t'$ is the main bar of the balance; and $t\ b$, $t'\ b'$ are two compound bars, of which the outer part is of brass, and the inner part of steel, carrying weights, b, b', which may be screwed on at different places. The brass bar expands more with heat, and contracts more with cold than the steel bar; therefore, as the temperature rises, the bars, with their weights, bend inwards, and so the moment of inertia of the balance is diminished; as it falls, they bend outwards, and the moment of inertia is increased; and of course the diminution or the increase must be made exactly to correspond to the diminution or increase in the force of the spring.



CHRONOMETERS.

The chronometer is just a large watch fitted with all the contrivances which experience has shewn to be conducive to accurate time-keeping—for example, the cylindrical balance-spring, the detached escapement, and the compensation-balance. As a watch which will keep time in one position will often not do so equally well in another, marine chronometers are always set horizontally in a box in *gimbals*, an arrangement which keeps the chronometer horizontal, whatever the motion of the vessel.

The great importance of an accurate portable time-keeper at sea is for determining the longitude. From what has been already said on the subject of time, it will be readily understood that if the captain of a ship, leaving a port in Great Britain with a chronometer set to Greenwich time, shall, after sailing westward for a time, observe when the sun is at his highest point, or on the meridian, and find that his chronometer at that instant marks one o'clock, he must be 15° west of Greenwich. This use was first distinctly pointed out by Sir Isaac Newton. A committee of the House of Commons, of whom this philosopher formed one, having been appointed, on the 11th June 1714, to consider the question of encouragement for the invention of means for finding the longitude, the result of their meetings was a memorial containing an explanation of the different means proper for ascertaining the longitude, and recommending encouragement for the construction of chronometers as the best means of ascertaining it. An act of parliament was then passed, offering a reward for this purpose.

The first chronometer used at sea was invented by John Harrison. After many years of study, it was completed in 1736. After several further trials and improvements, and two trial voyages to America, undertaken for the satisfaction of the commissioners, the last of which was completed on the 18th September 1764, the reward of £20,000 was finally awarded to Harrison.

Somewhat later than this, several excellent chronometers were produced in France by Berthoud and Le Roy, to the latter of whom was awarded the prize by the Académie Royale des Sciences. Progress was still made in England by Arnold, Earnshaw (the inventor of the compensation still in use), and Mudge, to whom prizes were awarded by the Board of Longitude, and

under whom a perfection nearly equal to that of the present day was obtained. The subsequent progress of watch-making has been chiefly directed to the construction of pocket-watches on the principle of marine chronometers, or to the combination of accuracy with convenient portability. The adjusted lever watch is now made in Clerkenwell with a degree of accuracy which enables the performance to be warranted within an error of one second a day.

USEFUL HINTS.

For the attainment of habits of punctuality, for the regulation of the usual routine of business and of everyday life, much often depends on the judicious selection of a time-keeper. Although, therefore, none but a workman possessing a thorough knowledge of his art is capable of forming a certain judgment regarding the merits of a particular watch or clock, yet a few general hints may not be without use. With this view we select the following remarks from an excellent little work published some years ago—Thomson's *Time and Time-keepers.*

And first of clocks: These, in general, measure time more accurately than watches, especially eight-day weight or long clocks, which are also cheapest. Long and heavy pendulums are to be preferred. A light pendulum shews a clock to be badly constructed, or deficient in power. Steel rods are better than brass, well-seasoned and varnished wood than steel, and compensation-rods than either. The clock should be steadily fixed to the wall, or firmly placed on *three* feet sufficiently far apart, so that the mechanism may be uninfluenced by the oscillations of the pendulum. Clocks are regulated by lengthening the pendulum, to make them lose, and by shortening it, to make them gain; this is very generally done by turning a nut or screw *below* the weight or *bob* of the pendulum, *to the right to gain*, or *to the left to lose;* or, if the screw is *above* the weight, the rule is *reversed.* Many French clocks, and a few old English ones, are liable to derangement in striking, unless the hands are moved rapidly *forward.* The hands of English clocks, in general, may be turned either way without injury, and the same with a watch, unless it has an alarm.

An intelligent, careful man may be safely trusted with the cleaning, adjusting, or repairing of clocks, while a diversity of talent and experience is necessary to qualify him for the manipulation of watches. 'The possessor of a good picture would doubtless inquire into the ability of the artist before he intrusted him to retouch it; and this caution is equally necessary for a watch, as many of the best construction have sustained irreparable injury from the hands of unskilful workmen. Even bad watches—which are by far the greatest number—require the aid of better hands than those which constructed them.' A clever artist may enable even a bad watch to perform tolerably well. Watches should ordinarily be cleaned every second or third year; small, flat, or complicated ones oftener. All require care in handling. They should be regularly wound as nearly at the same hour as possible; and while being wound, should be held steadily in the hand, so as to have no circular motion themselves. When hung up, let the watch have support, and be perfectly at rest; or when laid horizontally, let it be placed on a soft substance for more general support, otherwise the motion of the balance will generate a pendulous motion of the watch, causing much variation in time. Should a watch vary by heat or cold, as when worn or not worn in the pocket, the hands may be set to time; but the regulator should not be altered, if set to the ordinary temperature of the season. Compensation watches, if properly constructed, do not so vary. A trial even of a year or two is no proof of the substantial worth of a watch. Dealers themselves may be deceived. A duplex watch may be very bad, while a vertical one may be very good, so that workmanship is as important as principle. Many low-priced and bad watches have eight or even ten holes jewelled, while many good and costly ones have but four: a hole can be jewelled for three shillings. 'The high-sounding description, the handsome exterior, the offered trial, and enticing cheapness, are effective baits to the short-sighted.' External ornament forms but a small item of expense, and the prices therefore will, in general, point out the comparative qualities of the work in the shop of an artist of known integrity and ability.

The large thick old watch is less absurd than some of the more recent kind, little thicker than half-a-crown, or even much smaller. The lever watch is capable of great accuracy, and is preferable to the vertical, though the principle of the latter is more generally understood, and more easily repaired; lever watches, however, are neither expensive to repair nor liable to derangement. The horizontal or cylinder watch is liable to great tear and wear, but performs with considerable accuracy. The duplex watch, with a compensation-balance, when well constructed, and treated with ordinary care, will keep time with the greatest accuracy; but being delicate, it does not stand violent exercise: a bad duplex watch is most expensive to repair. The detached watch, the escapement of which is the only one used in marine chronometers, is the most perfect, but requires care. Repeaters are expensive to repair as well as to purchase, but may be as accurate as others. Watches shewing seconds are often useful, and, if well made, are neither expensive nor easily deranged. A watch may be handsome, yet bad; but a good watch is seldom unsightly. The spring for shutting the shells is not so good as the snap; it often allows dust to penetrate to the works. The covers of hunting-watches will not protect the glass when the hunters are very flat. The extreme accuracy of marine chronometers is partly produced by their being kept constantly in a horizontal position. They are only required to shew *equal* time; whether they gain or lose is of little consequence, provided they are regular, and *keep* their known rate.

CHEMISTRY.

CHEMISTRY is a department of physical science, and therefore treats of the properties and changes of matter.

As the division of physical science into various departments depends more upon the various methods which we use in observing the phenomena of nature, than upon any real natural distinction, it is impossible to give a logically complete definition of any of these departments; and what now belongs to one, it may be found, at some future time, more convenient to transfer to another. We shall, therefore, neither quote any of the numerous definitions of chemistry already given, nor add one to the number, but leave the reader to form an idea of its scope and purpose from the outline of the facts and principles of the science contained in the present paper.

Matter, whether as it occurs in nature, or as modified by art, is obviously of various kinds, and any specimen of matter that we may examine is either all of one kind, or a mixture of several different kinds. There are various means by which we can determine whether a specimen of matter is pure (that is, all of one kind) or not.

We can often prove that a substance is a mixture by simple inspection. Thus, any one who looks at a piece of granite at once sees that it consists, not of one substance, but of a mixture of several, the particles of each being large enough to be distinctly visible. The smaller the particles, and the more intimate the mixture, the more difficult does it become to distinguish it, by simply looking at it, from a pure, single substance. Where the eye cannot settle the question, we must resort to other means. These may be described generally as ways of 'taking samples.' If samples taken in many different ways agree with one another, and with the original substance, we conclude that we have to deal with a pure body; if, on the contrary, the samples differ from one another, we learn that the substance is a mixture, and, further, find out how to separate it into its several ingredients. We shall describe a few of these 'tests of purity,' or ways of taking samples.

1. *Elutriation.*—In the first case, we shall suppose that we have a substance, no part of which dissolves in water, and which consists of very small particles of two or more bodies of different specific gravity. The substance is reduced to a fine powder, and stirred up with water. This is left for a time at rest, and gradually a part of the powder separates—if heavier than water, as a sediment at the bottom; if lighter than water, as a scum at the top. The scum is then removed, or the muddy water poured off from the sediment and again left at rest, when a further portion separates; and by repeating this process, we obtain a series of samples differing from one another in the rate of deposition. If the substance were all of one kind, these samples would only differ from one another in the *size* of the particles, the largest separating most rapidly; but if we have a mixture, we find that (supposing the particles of the different ingredients to be of the same average size) the particles which are denser than water go down the faster the denser they are, and the particles lighter than water rise to the surface the faster the lighter they are, so that the first sample differs in kind from the last. This method of 'elutriation' is exemplified in the washing of ores; the lighter clay or earth with which the ore is mixed, falling slowly through the water, is washed away as mud, while the heavier ore falls quickly to the bottom of the vessel in which the washing is performed, and is thus retained.

2. *Solution.*—Some substances, such as sugar, salt, &c. dissolve in water; others, such as sand, charcoal, &c. do not. We can therefore detect a mixture of a soluble and an insoluble substance, and separate them from one another, by treating the mixture with water until no more will dissolve: we have then the insoluble substance left, and can recover the soluble one from the liquid by evaporating away the water. This process, sometimes called 'lixiviation,' is used in extracting saltpetre from earth containing it, in obtaining potash from wood-ashes, and in many other important operations. Other liquids besides water may be used for similar purposes, a liquid being selected which will dissolve some of the ingredients in the mixture and leave others undissolved. The solution is separated from the insoluble residue, either by allowing the latter to settle and then decanting, or by filtration.

3. *Crystallisation.*—Substances soluble in water require very various proportions of water to dissolve them; thus 100 parts of water will, at the ordinary temperature, dissolve 33 parts of Epsom salts, 20 parts of washing-soda, 10 parts of bicarbonate of soda (common 'baking-soda'), and about one-third part of plaster of Paris. If, then, a mixture of soluble substances be dissolved in water, and the water gradually evaporated, the least soluble of these substances will separate first; and by collecting separately the successive crops of crystals, we shall have a series of samples, the first consisting almost exclusively of the least soluble, the last of the most soluble. Such a method of separation is seldom perfect, each crop generally containing some admixture of the ingredients prevailing in the crop before and in that after it. It is in this way that common salt is obtained from sea-water. Sea-water contains, besides common salt, smaller quantities of various other salts. Of these the least soluble is sulphate of lime, and this is the first to appear on evaporating the water; the common salt crystallises next; and the 'mother-liquor,' as the solution left after the common salt has been removed is called, contains salts of magnesia, which are very soluble.

4. *Dialysis.*—If a solution of common salt be securely tied up in a bladder, and the bladder be hung in a vessel filled with pure water, it will be found after a time that the water outside the

bladder is as salt as that within; and if the water outside be frequently renewed, the whole of the salt can be removed from the bladder. If, instead of a solution of salt, we take a solution of glue (weak enough to prevent its *setting* as a jelly), we find that practically none of the glue escapes into the outer vessel. If a mixture of salt and glue be treated in this way, the two substances will be separated—the salt passing through the bladder, and the glue remaining behind. Many substances, especially those which crystallise, behave like salt, and pass through the bladder; while many other substances, especially those which, like glue, do not crystallise, but form jellies, and, when dried, appear as horny masses, pass extremely slowly through the bladder. The late Mr Graham, Master of the Mint, who discovered this method, called the first set of bodies 'crystalloid'—that is, crystal-like; and the second, 'colloid'—that is, glue-like bodies. Dialysis is used in detecting poisons in animal fluids, such as the contents of the stomach. Most of the important poisons are crystalloid; while most of the animal fluids that interfere with the detection of poisons are colloid, so that the two can be separated by this means. Dialysis has also been applied to remove the salt from the brine in which meat has been salted. Such brine contains much nutritious matter dissolved out of the meat, but is far too salt to be used as food; by dialysis the salt can be removed, while the nutritious matter, being colloid, remains in the bladder.

5. *Fusion.*—A mixture of a fusible and an infusible substance may be resolved into its ingredients by heating it till the fusible body melts, and then pressing it, or allowing it to drain away from the infusible residue. The same method may be employed to separate from one another two substances of different degrees of fusibility, by heating the mixture to a temperature higher than the fusing-point of the one, and below the fusing-point of the other.

6. *Distillation.*—Some substances are *volatile*—that is, can be converted by the action of heat into vapour, which, when cooled, is condensed, or restored to the liquid or solid state. By distillation we can separate volatile from non-volatile bodies. The mixture is heated in a vessel (retort or still), to which a tube is adapted, to convey the vapour to the 'condenser,' where it is cooled. The

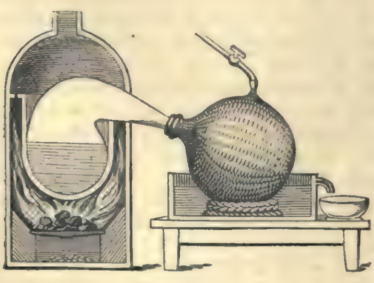


Fig. 1.

volatile substance distils over, while the non-volatile ingredient remains in the retort or still. By what is called *fractional distillation*, it is possible to separate, more or less completely, substances of different degrees of volatility; the first portion of the distillate contains a larger proportion of the more volatile ingredient, and the last a larger proportion of the less volatile. Thus, when the 'wash,' or liquid formed by the fermentation of malt, is distilled, the first portion consists of a very volatile product called the 'foreshot;' then alcohol mixed with water distils over; and lastly, a substance less volatile than alcohol, the 'fousel oil.'

7. *Diffusion of Gases.*—If a heavy gas and a light gas are placed together in a vessel, the heavy gas below and the light above, they slowly mix, even when left at rest; but, when once mixed, they shew no tendency to separate; and however long the mixture is kept, the mixture at the top will be found to have the same composition as that at the bottom. It is, therefore, often necessary to apply a test, in order to determine whether a given specimen is a single gas or a mixture. Some of the methods already mentioned may sometimes be employed for this purpose. Thus, gases differ in their solubility, and in this way it may be shewn that atmospheric air is a mixture, one of its ingredients (oxygen) being considerably more soluble in water than the other (nitrogen). Again, some gases can be condensed into liquids by cold and pressure, and thus partially separated from those which cannot be so condensed. By this means Faraday discovered in oil-gas the gas now known as butylene.

There is, however, a special method by which, in almost all cases, mixtures can be distinguished from single gases.

The slow mixing of two gases, of which we have just spoken, and which is known as 'diffusion' of gases, takes place not only when the two gases are in immediate contact, but also when they are separated by a porous septum (such as a plate of unglazed earthenware), and in this case it is easy to measure the 'rate of diffusion' by observing what quantity of gas passes through the septum in a given time. Now, different gases have different rates of diffusion—the lighter the gas the faster does it diffuse.* If, then, a mixture of two gases of different density be allowed to diffuse through a porous plate, more of the lighter gas will pass out, and proof will be obtained that the specimen was a mixture, and not a single gas.

The various methods of which we have given a general description are physical or mechanical modes of separating completely or partially the ingredients of a mixture, and thus, more or less perfectly, obtaining pure substances. Let us now consider some of the properties of these pure substances. For this purpose, it is necessary to classify them, or arrange them in groups. This may be done in several different ways. We may, for instance, distinguish them as, first, simple; and second, compound. A compound substance is one which we can, by the application of some process, separate into two or more pure substances, different from each other and from the original substance. We shall give an instance, and shew how a compound differs from a mixture. White statuary marble is a pure body; it cannot, by any mechanical process, such as we have described above, be separated into ingredients—any such mechanical mode of sampling

* Experiment has shewn, in complete accordance with theory, that the rate of diffusion is inversely proportional to the square root of the density of the gas.

it yields samples identical with one another. But if we weigh a piece of marble in a crucible, the weight of which is known, and then raise it to a bright red-heat, we find that, upon cooling, it weighs less than it did before. If we continue the heating until no further change of weight is produced, we find that one hundred parts of marble are reduced to fifty-six. Something must have been lost in this process, and we are able, by methods—the details of which we cannot at present describe—to shew that this something is a gas, or kind of air, which the marble gives off when strongly heated. By appropriate means we can catch this air, and shew that one hundred parts of marble give off exactly forty-four parts of it by weight. What is left in the crucible is not marble—it differs entirely from it in appearance and properties—it is quicklime. We have thus decomposed marble into two substances, quicklime, and a gas, which its discoverer, Dr Black, called 'fixed air,' because it had been in a fixed or solid condition in the marble. We shall afterwards see what this gas is—in the meantime we shall call it fixed air. By heating marble we have then obtained from it two different substances, lime and fixed air : but it will be at once seen that this *decomposition* is quite another thing from the separation of a mixture into ingredients. Marble is not a *mixture* of lime and fixed air ; it is a pure substance, having properties of its own ; thus, lime and fixed air are both soluble in water, marble is not ; marble is tasteless, while both of the bodies formed from it have well-marked tastes. The space occupied by a piece of marble is not the same as that occupied by the lime and fixed air which can be obtained from it. On the other hand, the properties of the ingredients of a *mixture* remain unchanged—that is, are the same in the separate and in the mixed state ; and the space occupied by the mixture is the same as that occupied by the ingredients unmixed.

A large number of substances can be *directly* decomposed by the action of heat, light, or electricity, and thus proved to be compounds, as we have seen is the case with marble ; and in many cases we can reverse the process, and prove that a substance is compound by forming it from its components ; thus, quicklime and fixed air unite and form a substance identical in chemical characters with marble.*

By this process of 'synthesis' (or *putting together*) we can often prove that substances which we are unable to decompose directly are really compounds. Thus, quicklime cannot be decomposed without the addition of some other substance, but we can prove it to be a compound by effecting its synthesis. The metal calcium, which can be obtained from lime by a series of processes which will be described in a later part of this paper, unites with oxygen gas, and the resulting compound is quicklime. The compound character of quicklime, and the nature of its components, are as clearly proved by this synthesis as they could be by the direct decomposition of quicklime into calcium and oxygen. There are, however, a considerable number of substances (sixty-three are at present known) which chemists have not as yet been able either to decompose, or to produce by synthesis. Such substances have, therefore, not been proved to be compound, and are provisionally styled 'elements,' or simple bodies. All compounds are composed of two or more of these *elements* united together ; and compounds are sometimes classified as binary, ternary, quaternary, &c. according as they consist of two, three, four, &c. elements.

A more generally useful system of classification of pure substances is to arrange them in groups or natural families according to their resemblances in chemical action. This system will be best illustrated by means of examples, and for this purpose we shall select five groups, which include the most important and useful substances, and the relations of which exhibit most strikingly the nature of chemical action. These five groups are (1) Acids, (2) Bases, (3) Salts, (4) Metals, and (5) Salt-radicals.

As particular examples of these groups, we may here mention the following substances—(1) Acids : Sulphuric Acid (oil of vitriol), Nitric Acid (aquafortis), Hydrochloric Acid (spirit of salt), Acetic Acid (vinegar). (2) Bases : Caustic Potash, Caustic Soda, Lime, Magnesia, Oxide of Lead (litharge), Ammonia (spirit of hartshorn). (3) Salts : Sulphate of Soda (Glauber's salt), Sulphate of Magnesia (Epsom salt), Chloride of Sodium (common salt), Chloride of Ammonium (sal-ammoniac), Acetate of Lead (sugar of lead), Nitrate of Potash (saltpetre). (4) Metals : Potassium, Sodium, Calcium, Magnesium, Zinc, Iron, Copper, Silver. (5) Salt-radicals : Chlorine and Iodine.

If we examine the acids above mentioned, we find that they possess certain well-marked characters in common. They have all a sour taste ; they all act in the same way upon blue and purple vegetable colours (such as the colouring-matter of the violet, or of the red cabbage, or the colouring-matter called *litmus*, obtained from certain lichens), turning them red. These two characters —the sour taste, and the 'acid reaction,' as the reddening of vegetable blue colouring-matters is called—belong to most acids which are soluble in water. The taste of the soluble bases is not so generally characteristic, although many of them have a peculiar so-called 'alkaline' taste—resembling that of soap—well marked in potash, soda, and lime. The change which they produce upon the above-mentioned vegetable colouring-matters is exactly the reverse of that of the acids, and is called the 'alkaline reaction.' Thus, if we take a purple infusion of red cabbage, and add potash, soda, lime, or ammonia to it, it becomes green ; if to this green liquid we cautiously add an acid, it becomes purple, and then red ; an addition of a soluble base (alkali) to this red liquid renders it first purple, then green. Similarly, blue litmus is reddened by acids, and reddened litmus has its blue colour restored by the addition of an alkali. Another substance which is used as a test for the alkaline reaction is the yellow colouring-matter of the turmeric root—this is rendered brown by alkalies, and the yellow colour is restored on adding an acid. These characters (taste and reaction) belong to well-marked acids and bases which are soluble in water ; they do not belong to *all* acids and bases. The distinguishing character of these groups is *their action upon each other*.

* Sir James Hall has shewn that if this substance (*amorphous* or *uncrystallised carbonate of lime*) is heated under great pressure, it does not decompose, but fuses, and, on cooling, forms a substance in all respects the same as white marble.

When an acid and a base are mixed, a salt is produced. Thus, if we gradually add a solution (in water) of hydrochloric acid to a solution (in water) of caustic soda, a point will be reached where the mixed solution has neither the alkaline reaction of the soda nor the acid reaction of the hydrochloric acid. Such a solution is said to be *neutral*, and, on examination, is found to contain neither acid nor base, but a new substance, different from either of them. In the case which we have taken, this neutral substance is common salt. A similar action takes place between every acid and every base, and the fact that salts are formed in this way has given rise to the nomenclature of salts which was till lately in almost universal use, and is still very frequently employed. This nomenclature will be best explained by a series of examples. Thus,

Sulphuric Acid	acts on	Soda,	producing	Sulphate of Soda.
Nitric Acid	"	Soda,	"	Nitrate of Soda.
Hydrochloric or Muriatic Acid	"	Soda,	"	Hydrochlorate or Muriate of Soda.
Sulphuric Acid	"	Ammonia	"	Sulphate of Ammonia.
Acetic Acid	"	Oxide of Lead	"	Acetate of Oxide of Lead.
		&c. &c.		

In all these cases, the name of the acid ends in *-ic* (sulphur*ic*, nitr*ic*, &c.). There are, however, acids the names of which end in *-ous*, such as sulphur*ous* acid, nitr*ous* acid. In such cases,

Sulphurous Acid	acts on	Soda,	and produces	Sulph*ite* of Soda.
Nitrous Acid	"	Potash,	"	Nitr*ite* of Potash.
		And so on.		

Sulphur*ic* Acid produces sulph*ates*; Sulphur*ous*, sulph*ites*, &c.

When this characteristic action of an acid upon a base takes place, water is in most cases produced as well as the salt. This formation of water is of great theoretical importance, and will be adverted to again further on.

What we have now seen enables us to define acids and bases as substances opposed to one another in chemical character, and capable of acting upon one another, so that both the acid and basic properties are neutralised, and salts produced. It is necessary, however, to note that this distinction between acids and bases is one rather of degree than of kind, some acids possessing the acid character, and some bases possessing the basic character, in a much more strongly marked manner than others. Thus, some substances behave as acids with strong or well-marked bases, and as bases with the stronger acids; for instance, white arsenic has decidedly acid properties, and forms salts with most bases, but acts like a base when treated with hydrochloric or tartaric acid. Alumina and green oxide of chromium are bases to most acids, but acids to some of the stronger bases, such as potash and lime. The salts formed from a strong acid and a weak base have, generally speaking, when soluble, an acid reaction; those formed from a weak acid and a strong base have, under similar conditions, an alkaline reaction. Thus, sulphate of alumina has an acid reaction; carbonate of potash has an alkaline reaction.

The next point which we shall consider is the relation between the *quantity* of acid and the *quantity* of base required to form a salt. This is most easily investigated in the case of strong acids and bases which form with one another salts neutral to vegetable colours, although the same principles apply equally to all other cases. To illustrate these principles, we shall examine the relations of the acids and bases mentioned above—namely, sulphuric, nitric, hydrochloric, and acetic acids; and the bases, caustic potash, caustic soda, lime, magnesia, oxide of lead, and ammonia. Let us first take a certain weighed quantity of pure caustic potash (for reasons to be explained afterwards, we select the quantity 56 grains*), and find out how much of each of these acids is required to neutralise it and form a salt. The results are as follow:

56 grains of Caustic Potash are neutralised by—

49	grains of	Sulphuric Acid.
63	"	Nitric Acid.
36½	"	Hydrochloric Acid.
60	"	Acetic Acid.

These quantities—49 parts of sulphuric acid, 63 of nitric acid, 36½ of hydrochloric acid, and 60 of acetic acid—are said to be 'equivalent' to one another—that is, they are equivalent as far as neutralising potash is concerned; and these numbers are called the 'equivalents' of the acids. We further find that

49 grains of Sulphuric Acid neutralise—

56	grains of	Caustic Potash.
40	"	Caustic Soda.
28	"	Quicklime.
20	"	Calcined Magnesia.
111½	"	Oxide of Lead.
17	"	Ammonia.

Similarly, these quantities of the various bases are said to be 'equivalent' to one another, and these numbers are called the equivalents of the bases. Now, the remarkable fact in connection with these numbers (the first discovered of a series of similar facts, upon which the modern system of chemistry is based) is, that *an 'equivalent' of any acid is precisely the quantity required to act upon an 'equivalent' of any base in order to produce a salt.* Thus, 63 grains of nitric acid neutralise 56 grains of potash, 40 of soda, and so on; 60 grains of acetic acid act upon 111½ of oxide of lead to produce sugar of lead, &c. It is thus only necessary to ascertain by experiment the proportion in which a new base unites with *one* known acid, in order to know in what proportion it will unite with any other acid the equivalent of which is known.

The salts thus formed are often called 'neutral salts,' because, when an equivalent of a *strong* acid acts upon an equivalent of a *strong* base, the resulting salt has neither an acid nor an alkaline reaction; it is, however, better to call them 'normal salts,' because, as already mentioned, such of them as have a weak acid and a strong base are often alkaline, and those with a strong acid and weak base are often acid in reaction upon vegetable colours. They are called 'neutral' or 'normal' salts, to distinguish them from two classes of salts which we shall next, shortly, advert to. If we mix 49 grains (one equivalent) of sulphuric acid with water, and add 56 grains (one equivalent) of caustic potash, we already know that the 'normal' sulphate of potash will be produced. If, however, we add only 28 grains (½ equivalent) of caustic potash, and then dry off the water, we find, not, as we might expect, a mixture of neutral sulphate of potash and unacted-on sulphuric acid, but a salt, called the 'bisulphate of potash,' or 'acid' sulphate of potash, which has been formed by the action of one equivalent of

* Instead of grains, it need scarcely be said, any other unit (ounces, pounds, or tons) may be used.

sulphuric acid upon half an equivalent of caustic potash (or, what is the same thing, by the action of two equivalents of sulphuric acid upon one of caustic potash). It is in the case of only some acids that we obtain acid salts: thus, sulphuric, oxalic, tartaric, phosphoric, citric acids form acid salts; nitric and hydrochloric acids do not. As examples of acid salts, we may mention cream of tartar (acid tartrate of potash), salt of sorrel (acid oxalate of potash), baking-soda (bicarbonate of soda), super-phosphate of lime (acid phosphate of lime). In these, we have salts formed from one equivalent of potash, and two of tartaric acid; one of potash, and two of oxalic acid; one of soda, and two of carbonic acid; one of lime, and three of phosphoric acid. It will be noted that here also we have the proportion of acid and base occurring according to equivalents; and it will be well to remember, what will be more fully explained afterwards, that it is the acid which determines the formation of acid salts, some acids forming them, others not.* Most acid salts have an acid reaction; but where the acid is weak, the reaction may be neutral, or even alkaline.

Again, we have seen, that if 60 grains (one equivalent) of acetic acid be treated with $111\frac{1}{2}$ (one equivalent) of oxide of lead, a normal salt (acetate of lead, or sugar of lead) is produced. If this be dissolved in water, and the solution be shaken up with finely divided oxide of lead, it will dissolve 223 grains (two equivalents) more, and form a salt, which is called 'basic' acetate of lead. A basic salt is formed by the action of one equivalent of an acid upon more than one equivalent of base; just as an acid salt is formed by the action of more than one equivalent of acid upon one of base; and as it is the acid which determines the formation of acid salts (some acids forming them, others not), so it is the base which determines the formation of basic salts; some bases, such as oxide of lead, oxide of bismuth, red oxide of iron, forming them; others, such as caustic potash, soda, oxide of silver, not.

Another class of salts deserves mention here —namely, the 'double salts.' These may be regarded as compounds of two salts with one another. As examples, we may mention common alum, consisting of sulphate of potash, and sulphate of alumina; Rochelle salt, tartrate of potash, and tartrate of soda; dolomite, carbonate of lime, and carbonate of magnesia.

We have now considered, pretty fully, the action of acids upon bases; let us specially turn to the action of acids upon salts, of bases upon salts, and of different salts upon one another.

In order to understand the action of acids upon salts, we shall first examine what takes place when an equivalent of a base is mixed with an equivalent of each of two acids. It is obvious that one or other of two things may occur— First, the base may form a salt with *one* of the acids, the remaining acid being left as it was; or second, the base may be divided into two parts, one forming a salt with part of the one acid, the other with part of the other acid, the rest of both acids being left unacted on. In the first case, we shall have a mixture of *one* salt and *one* acid; in the second, a mixture of *two* salts and *two* acids. Thus if one equivalent ($111\frac{1}{2}$ grains) of oxide of lead be mixed with one equivalent (49 grains) of sulphuric acid, and one equivalent (63 grains) of nitric acid, the whole of the oxide of lead acts on the sulphuric acid, and the nitric acid is left altogether unacted on. Again, if one equivalent (40 grains) of caustic soda be mixed with one equivalent of sulphuric, and one equivalent of nitric acid, the soda acts on both acids, producing sulphate of soda and nitrate of soda, while a part of both acids is left unacted on. Now, the same final result is produced whether the two acids are added at once (as in the cases we have just mentioned) or successively. In the first case, we might add to the oxide of lead, first, nitric acid, and obtain nitrate of lead; and then to the nitrate of lead add sulphuric acid, when we should obtain sulphate of lead and nitric acid—the sulphuric acid turning out (if we may use the phrase) the nitric acid. If, on the other hand, we add the sulphuric acid first, we obtain sulphate of lead, and nitric acid does not act on this; so that in either case we obtain the same final result—sulphate of lead and nitric acid. In the second case, sulphuric acid will *partially* (at ordinary temperatures) drive out nitric acid from nitrate of soda, and nitric acid will also *partially* drive out sulphuric acid from sulphate of soda; in either case, producing a mixture of sulphate of soda and nitrate of soda, sulphuric acid and nitric acid. We have said 'at ordinary temperatures,' and this leads us to a point of great theoretical and practical importance. It is obvious that the balance of the mixture will be destroyed, that is, the proportion in which the base is divided between the acids will be changed, if a part of one of the acids be taken away. Thus, if, in the last-mentioned case of a mixture of sulphate of soda, nitrate of soda, sulphuric acid, and nitric acid, we take away some of the nitric acid, a rearrangement will take place; the soda will be divided between the two acids in proportion to the quantities of them *now* present, a new quantity of nitric acid will be driven out by sulphuric; so that, if we continue to remove the nitric acid as it is formed, the nitrate of soda will be *entirely* decomposed, and nothing but sulphate of soda will be left. Now, nitric acid is much more volatile than sulphuric acid; therefore, by heating the mixture, we can remove the nitric acid as vapour, leaving the sulphuric acid in the mixture; and thus, although at ordinary temperatures, below the boiling-point of nitric acid, sulphuric acid only partially decomposes nitrate of soda, at higher temperatures the decomposition is complete, the nitric acid passing off as vapour. It is, of course, not necessary that one of the acids should be removed *as vapour;* the same result follows, in whatever way it is taken out of the mixture; thus, it may separate as a solid out of an aqueous solution—as, for instance, is the case when an aqueous solution of borax (borate of soda, the salt formed by the action of soda on boracic acid) is treated with sulphuric acid. Here the sulphuric acid drives out the boracic acid, and as the latter is only sparingly soluble in cold water, a large part of it crystallises out, and the borax is almost wholly decomposed. The consideration of the fact, that, as a general rule, a base is shared between the acids which, so to speak, compete for it; and that when one acid is partially removed,

* There are some bases which seldom or never form acid salts, even with those acids which have the greatest tendencies to form them; thus, there are no acid salts of oxide of silver.

the one which is left gets a larger share, enables us to explain some apparently anomalous cases of decomposition. Thus, as we have seen, in a cold aqueous solution sulphuric acid decomposes borate of soda, driving out boracic acid, and forming sulphate of soda ; but if we mix sulphate of soda and boracic acid, and heat the mixture strongly in a crucible, we find that the boracic acid drives out the sulphuric acid, and forms borate of soda : in the first case, the boracic acid is removed by becoming solid ; in the second, the sulphuric acid is removed by being converted into a vapour.

The balance in such a mixture as we have been considering may be disturbed, and a rearrangement necessitated, by the removal of one of the salts, as well as by the removal of one of the acids. Thus, if we mix an equivalent of nitrate of lime* with one equivalent of sulphuric acid, and a sufficient quantity of water to retain the whole in solution, the lime is divided between the nitric and sulphuric acids, so that we have a mixture of sulphate of lime, nitrate of lime, sulphuric acid, and nitric acid. If to this mixture we add alcohol (spirit of wine), a change of conditions is produced, for sulphate of lime is insoluble in dilute alcohol. The result is, that the sulphate of lime is precipitated,† and the sulphuric acid in the liquid acts upon the nitrate of lime, producing more sulphate of lime, which is also precipitated, and so on until the whole of the nitrate of lime is decomposed, and nothing is left but sulphate of lime as a precipitate, and nitric acid in solution.

The action of acids upon salts is taken advantage of in the preparation of many acids. Thus, nitric acid is prepared by the action of sulphuric acid on nitrate of soda ; hydrochloric or muriatic acid, by the action of sulphuric acid on common salt (which we may call muriate of soda) ;‡ tartaric acid, by the action of sulphuric acid on tartrate of lime, &c. It is also used in analysis, as will be explained when we come to that branch of the subject.

The action of bases upon salts will be easily understood from what has just been said of the action of acids upon salts. The new base may—first, totally decompose the salt, driving out the original base ; second, partially decompose it, the acid being shared between the two bases ; or, third, produce no change ; and as in the case of the acids, so here, a partial decomposition may be made complete by removing the base as it separates, or by removing the newly produced salt. It sometimes happens that the new base, taking part of the acid of the salt, leaves a basic salt ; thus, when ammonia is added to nitrate of lead, nitrate of ammonia is produced, and basic nitrate of lead. The latter being nearly insoluble in water, is precipitated.

The action of bases upon salts is taken advantage of in the preparation of bases ; thus, ammonia is prepared by the action of lime upon hydrochlorate of ammonia; caustic potash and caustic soda, by the action of lime upon carbonate of potash or carbonate of soda; oxide of silver, by the action of caustic potash upon nitrate of silver, &c.

* By an equivalent of a *salt* we mean the quantity formed by the action of an equivalent of acid upon an equivalent of base.

† When the mixture of two liquids causes the separation of an insoluble solid substance, the solid is said to be 'precipitated,' and is called a 'precipitate.'

‡ This nomenclature will be more fully explained farther on.

The action of salts upon salts.—Some salts may be mixed together without any action taking place. In the case of others, especially when one or both are in solution, an exchange of acids and bases takes place, which may be, as in the actions just described, either complete or partial. Thus, if we mix one equivalent of nitrate of lead and one equivalent of sulphate of soda, both dissolved in water, we obtain an equivalent of sulphate of lead and an equivalent of nitrate of soda. Such an action is called double decomposition. In this case one of the salts produced (sulphate of lead) is insoluble in water, and is therefore precipitated. When all four salts—namely, the two which are originally mixed, and the two which are or may be produced—are soluble in water, it is often difficult to make out whether double decomposition has taken place or not, and still more difficult to determine the exact extent of the change. As previously pointed out, a partial change may be rendered complete by the removal of one of the products, either as a precipitate or in the form of vapour. Thus, in the example given above, the double decomposition is complete, the sulphate of lead being precipitated ; and when carbonate of lime and muriate of ammonia are mixed, carbonate of ammonia and muriate of lime are produced, and the action is complete if the mixture be heated, because carbonate of ammonia is volatile, and is driven off as vapour.

Double decomposition is taken advantage of in the preparation of many salts, and also in chemical analysis.

In the sketch of the characters of acids, bases, and salts, and their relations to one another just given, we have omitted a very important point which we must now advert to ; this is, the relation of *water* to these classes of bodies.

Water enters into combination with a great variety of substances, and in different ways. Thus, many substances dissolve in water, and the solutions so formed are weak compounds of water and the substances dissolved ; weak compounds, because the components are easily separated, moderate heat driving off the water.* Again, many crystalline substances contain water as an essential constituent, without which they would either not crystallise at all, or crystallise in a different form ; hence called 'water of crystallisation.' This water also is feebly held in combination, and is easily driven off. Many crystalline substances containing water of crystallisation, lose it on exposure to dry air, losing at the same time their crystalline form. This change is called 'efflorescence,' and crystalline substances which undergo this change are said to be 'efflorescent.' Washing-soda is a familiar instance. The clear, transparent crystals of washing-soda contain nearly 63 per cent. of water of crystallisation. On exposure to dry air, they lose water, and become white and powdery. All substances containing water of crystallisation do not lose it so readily, but a temperature a few degrees above the boiling-point of water is sufficient to drive it off in every case. Now, there are soluble acids and soluble bases, there are crystalline acids and crystalline bases containing water of crystallisa-

* Although solutions may be said to be *weak* compounds because easily decomposed, many soluble substances have such a strong attraction for water, that they can remove it from moist air, and unite with it to form a solution ; such substances are said to be 'deliquescent,' and are used for the purpose of drying gases.

tion, but acids and bases enter into combination with water in another and special way. We have pointed out before that there are substances which may be said to be intermediate between acids and bases, which act as bases to strong acids, and as acids to strong bases. Now, water is such a substance. Water unites with many bases, forming substances called 'hydrates,' or 'hydrated bases' (thus, 'hydrate of lime,' 'hydrated oxide of lead,' &c.); it also unites with many acids, forming substances called 'hydric salts,' or 'hydrated acids' (thus, 'hydric sulphate,' or 'hydrated sulphuric acid,' &c.). This kind of combination of water with acids and bases was long confounded with one or other of the two kinds mentioned just before, and from this there has arisen a confusion in the nomenclature of acids, bases, hydrates, and hydric salts, which is very likely to prove perplexing to the beginner.

Thus, the term 'sulphuric acid' is used to express two different things—1. Oil of vitriol, which, when as strong as it can be made, consists of nearly pure 'hydric sulphate,' or 'sulphate of water;' and 2. A white, solid substance, which is oil of vitriol without the water. This white solid, when put into water, unites with it, giving out a great deal of heat, and forming oil of vitriol, or 'hydric sulphate.'

In the case of many other acids, we have the same double meaning of the word; we have the 'anhydrous' (that is, waterless) acid, and the compound of that with water—the hydrated acid, or hydric salt. Some chemists restrict the word *acid* to the hydric salt, and call the anhydrous acid the 'anhydride;' others restrict the name acid to the anhydrous substance, and call the hydrated acid a hydric salt. Thus, we have the name sulphuric acid applied to two substances—anhydrous sulphuric acid, or sulphuric anhydride; and hydrated sulphuric acid, or hydric sulphate. And these differ from one another in that the latter is a compound of the former with water.

As all the processes described in the preceding pages in illustration of the action of acids on other substances, were assumed to take place in water, it was not necessary to allude to this ambiguity, and the acids taken as examples (sulphuric, nitric, hydrochloric, and acetic) were supposed to be in the state of hydric salts. The question, indeed, would be one of only theoretical interest, if every acid existed in both forms. But there are some acids which occur *only* as hydric salts, others which occur *only* as anhydrous acids. Thus, carbonic acid gas dissolves in water, but does not combine with it to form a hydrated acid, or hydric carbonate. Again, oxalic acid cannot be obtained in the anhydrous form. If we try to drive off the water from hydrated oxalic acid (hydric oxalate), we find that the acid itself decomposes and breaks up into other substances. We shall return to the consideration of these relations when we come to speak of salt-radicals.

As acids (that is, anhydrous acids) unite with water to form hydrated acids, or hydric salts, compounds in which water acts as a base, so anhydrous bases unite with water also, forming hydrated bases or hydrates in which water acts as an acid; and here also we are apt to get into confusion with the names. Thus, the word lime is generally used to mean quicklime—the anhydrous base, but not unfrequently for what is properly called slaked lime, the compound of lime and water (hydrate of lime).

Having considered in a general way the characters of acids and bases, we shall now shortly examine their composition, for they are all compounds—that is, they can all be produced by the union of elements, and can all be decomposed or broken up by separating these elements from each other. And first, we shall investigate the composition of water, which is, as we have seen, both an acid and a base—an acid in relation to the strong bases; a base in relation to the strong acids.

Water, as is well known, was long regarded as a simple or elementary substance. It is one of the four 'elements' of the ancients—fire, air, earth, and water; and although we now know that water is decomposed in a great many chemical changes constantly taking place, and produced from its elements in some of the most familiar and frequent cases of chemical action, the real nature of these changes escaped the observation of chemists until a comparatively recent time. The discovery of the composition of water was made by Cavendish about the year 1781. He shewed that when hydrogen gas is burned in the air, water is formed; and that if, instead of common air (which contains about 20 per cent. of oxygen), pure oxygen is used, the hydrogen and oxygen disappear, and water is produced, and *that the weight of the water formed is the same as that of the hydrogen and oxygen which have disappeared.* He thus proved that water is formed by the union of hydrogen and oxygen—that it is a compound of these two gases. By measuring the quantity of each gas,* he ascertained the proportion in which they unite, and shewed that one volume of oxygen unites with two volumes of hydrogen. As oxygen weighs bulk for bulk 16 times as much as hydrogen, the proportion by *weight* is 8 parts of oxygen to 1 of hydrogen; that is, 1 oz. of hydrogen in burning will use up and unite with 8 oz. of oxygen, and produce 9 oz. of water; or 9 oz. of water can be decomposed into 8 oz. of oxygen and 1 oz. of hydrogen; and the 1 oz. of hydrogen will occupy a space twice as great as the 8 oz. of oxygen. The composition of water was discovered by the method of *synthesis*—that is, by forming it from its constituents. We can also prove it by analysis—that is, by decomposing it into its constituents. This may be done by passing through water a current of electricity, from a galvanic battery for instance, when the hydrogen will bubble up from the one wire (that connected with the zinc of the battery), and the oxygen from the other (that connected with the copper of the battery). The two gases can thus be collected separately, and measured, when it will be found that the hydrogen produced fills just twice the space filled by the oxygen.

Water is thus a compound of hydrogen and oxygen, or, in chemical language, an *oxide* of hydrogen; the compounds of oxygen with other elements being termed 'oxides.' Now, a very

* When the bulks of two or more gases have to be compared, they must be measured under the same pressure and at the same temperature, as a change of pressure or of temperature produces a change in the bulk of a gas.

large number of the anhydrous acids and anhydrous bases are oxides, and the anhydrous bases which are oxides are all oxides of metals.

This brings us to the consideration of the fourth group or family of substances mentioned in p. 307—namely, Metals.

Like all the other groups which we have examined, the metals possess certain characters in common, by which they may be recognised as belonging to the group; some of these characters are physical, some are chemical. The most marked physical characters of the metals are, the 'metallic lustre,' and the readiness with which they conduct heat and electricity. The metallic lustre is the name given to the peculiar brilliancy of a polished metallic surface. All metals, when polished, shew this lustre; but some substances which are not metals shew it also. Thus, 'black-lead,' or plumbago, which is not a metal, and is in no way related to lead, but is a form of carbon, has a brilliant metallic lustre; and a considerable number of compounds shew it also, such as iron pyrites and galena. The power of conducting heat and electricity is possessed to a greater or less extent by all substances; by some, however, to such a small extent, that they are usually called 'non-conductors;' as instances, we may mention glass, resin, gutta-percha. The metals differ greatly from one another in 'conductivity,' or the power of conducting heat and electricity; but they are, as a rule, much better conductors than non-metallic substances. In other physical properties, metals shew great variety—in fusibility, ranging from mercury, which is liquid at ordinary temperatures, and only freezes at about $-40°$ Fahr. to platinum, which requires the highest temperature we can produce for its fusion; and osmium, which has not yet been fused. Metals differ greatly in density; the lightest known simple solid and the heaviest—lithium and osmium—being both metals. Some metals are malleable and ductile—that is, they can be beaten into thin plates or leaves, and drawn into wire, as is the case with gold, silver, copper, and iron; others are brittle, and can be pounded into a powder in a mortar. This is the case with antimony and bismuth. Most metals are white or gray, but we have yellow gold and red copper. Some are very hard, others very soft. As examples among common metals, we may compare the hardness of iron with that of silver, and that of lead.

Let us now turn to the chemical characters of metals. We have just mentioned that all the anhydrous bases which are oxides are oxides of metals. We may now add further, that every metal has an oxide which is a base. It is possible, directly or indirectly, to obtain a compound of each metal with oxygen. Some metals, such as zinc, aluminium, and magnesium, unite with oxygen in only one proportion; others, such as iron, copper, lead, mercury, form each more than one oxide, the various oxides containing the metal and oxygen in different proportions. In the former case, the oxide is a base; in the latter case, at least one of the oxides is a base. Thus, the oxide of zinc, the oxide of aluminium, and the oxide of magnesium, are bases; two of the three oxides of iron, both of the oxides of copper, one of the three oxides of lead, and both of the oxides of mercury, are bases. We may therefore define a metal as an element which forms in combination with oxygen at least one base. There are two general principles which may be mentioned here: 1. The more readily a metal unites with oxygen, the more basic is the oxide; thus, sodium is more easily oxidised than magnesium, magnesium than zinc, zinc than copper, copper than silver; and soda (oxide of sodium) is a stronger base than magnesia (oxide of magnesium), magnesia than oxide of zinc; and so on. 2. When a metal forms two basic oxides, we usually find that that which contains the least oxygen is the stronger base. Thus, two of the oxides of iron are bases; one (ferrous oxide) contains iron and oxygen in the proportion of 7 to 2; the other (ferric oxide) in the proportion of 7 to 3; and the former is the stronger base.

We shall now examine the action of acids and salts upon metals. The anhydrous acids, as a rule, do not act at all upon metals. There are some exceptions to this rule, which we may have occasion to allude to farther on. The action of the hydrated acids or hydric salts on metals is quite analogous to that of other salts. We shall illustrate this action by one or two examples. If we take a clear colourless solution of nitrate of silver, and place in it a piece of bright clean copper, we see in a few minutes that the copper is covered over with a growth of what looks like soft white moss; this gradually increases, the liquid at the same time becoming blue. The white covering on the copper consists of small scales of silver, and the blue colour of the liquid is due to nitrate of copper. If we take enough copper, we can in this way decompose the whole of the nitrate of silver, separating the silver in the metallic state. Again, if we place a piece of clean iron in a solution of nitrate (or sulphate) of copper, metallic copper is deposited on the iron, the blue colour of the solution disappears, and we have a solution of nitrate (or sulphate) of iron.* Again, if we place a piece of iron in a solution of hydrated sulphuric acid (oil of vitriol), that is, hydric sulphate, we have hydrogen gas given off, and sulphate of iron remains in solution. In each of these cases we have one metal driving out another, and taking its place.† Copper drives out silver, iron drives out copper, and iron drives out hydrogen. In each such case, the metal which drives the other out is said to be 'positive;' that which is driven out is said to be 'negative.' Thus, silver is negative to copper; copper is positive to silver, but negative to iron; iron is positive to copper; and so on. By means of a number of experiments of this kind, we can arrange the metals in a series, beginning with the most negative, and ending with the most positive. If we examine this series, we find that the more 'positive' a metal is, the more basic is its most basic oxide. So that just as a strong base drives out a weak one, so the metal of a strong base drives out the metal of a weak one.

We have hitherto looked upon salts as compounds of acids and bases, but the reader will now see that they may also be represented in another

* This action may be taken advantage of to detect copper in a solution; thus, a steel fork is covered with a red deposit of copper when it is dipped in a jar of pickles which have been coloured green by means of copper.

† We here speak of hydrogen as a *metal*. Chemically it is so, for water (the oxide of hydrogen) acts as a base, and substances have been obtained which may be regarded as *alloys* of hydrogen.

way. Thus, we have spoken of sulphate of copper as a compound of

$$\underbrace{\text{Oxide of Copper, that is, Copper and Oxygen,}}_{\text{Base.}} \quad \text{and} \quad \underbrace{\text{Anhydrous Sulphuric Acid.}}_{\text{Acid.}}$$

But just as a strong base, such as potash, will decompose this salt, driving out the oxide of copper, and forming sulphate of potash, so a more positive metal than copper—for instance, zinc—drives out the copper, and forms sulphate of zinc, in which the base is oxide of zinc. Here it is the *metal* which is changed; all the rest remains as it was. We may therefore represent the salt as a compound of metal with all the rest of the salt, thus:

$$\underbrace{\text{Copper}}_{\text{Metal.}} \quad \text{and} \quad \underbrace{\text{Oxygen and Anhydrous Sulphuric Acid.}}_{\text{Salt-radical.}}$$

The *rest of the salt*, that which in union with metal forms the salt, is called the 'salt-radical.' In the case of the sulphates, and indeed of the majority of salts, the salt-radical has not been obtained *in the free state*—that is, by itself, and is only known *in combination* with metals, forming salts, and with hydrogen, forming the hydric salt or hydrated acid, thus:

$$\overbrace{\text{Hydrogen and Oxygen}}^{\text{Water.}} \quad \text{and} \quad \overbrace{\text{Anhydrous Sulphuric Acid.}}^{\text{Acid.}}$$

Salt-radical.

There are, however, a number of substances known, which, *in combination*, play exactly the part of the salt-radicals we have just been considering—that is, they unite with metals to form salts, and with hydrogen to form hydric salts, corresponding exactly in general properties to the hydrated acids. These substances are called 'halogens' (that is, salt-producers). We shall illustrate their characters by means of an example, and for this purpose we shall select the most important of them—namely, chlorine. Chlorine is a simple substance—in other words, it has not been decomposed—and thus differs entirely from the salt-radicals of the sulphates, nitrates, &c. which consist of anhydrous acid and oxygen, and have not been obtained in the free state. Chlorine, in the free state, is a greenish yellow gas with an acrid smell. It readily unites with hydrogen, forming the substance known as muriatic acid gas, or, from its composition, hydrochloric acid gas. This is a true hydric salt, possessing all the general properties of the hydrated acids. It acts upon bases, producing salts and water; it drives out weaker acids (in the hydrated form—that is, as hydric salts) from their salts. The salts thus formed we have in the former pages called 'muriates,' or hydrochlorates;' but we now see what they are; they are compounds of metals and chlorine, the oxygen of the metallic oxide (or base) uniting with the hydrogen of the hydrochloric acid to form water. They are hence called 'chlorides.' Thus, instead of 'muriate of soda,' we say 'chloride of sodium;' and so on. They are, however, true salts, undergoing all the changes and reactions common to salts. It will be noticed that *all* salts can be represented as compounds of metal and salt-radical, while some salts (such as the chlorides) cannot be represented as compounds of acid and base. This has led to a modification of the old names of many salts; thus, we often use the names sulphate of sodium (or sodium sulphate) instead of the old sulphate of soda. It must not be supposed that sulphate of sodium means a compound of sodium and sulphuric acid; it is a compound of sodium *and oxygen* and sulphuric acid (anhydrous).

We may now place side by side the various names given to the same salt:

Sulphate of Soda	Sodic Sulphate	Sulphate of Sodium.
Hydrated Sulphuric Acid	Hydric Sulphate	Sulphate of Hydrogen.
Muriate of Soda	Sodic Chloride	Chloride of Sodium.
Hydrochloric Acid	Hydric Chloride	Chloride of Hydrogen.
Nitrate of Oxide of Lead	Plumbic Nitrate	Nitrate of Lead.
&c.	&c.	&c.

Sulphate of soda means the salt formed by the action of sulphuric acid on soda; sulphate of sodium means the compound of sodium and the salt-radical of the sulphates; while sodic sulphate may be used to indicate the same substance without referring to either view of its constitution. For this, as well as for other reasons, the names in the middle column are to be preferred, although this system sometimes involves us in the use of novel and awkward adjectives, such as zincic, or bismuthous.

We have seen that many bases are oxides of metals, and we must now attend to the relation of the metals to their oxides. When a metal (or other substance) is made to unite with oxygen, it is said to be 'oxidised;' when the oxygen is taken away from an oxide, and the original substance (whether metal or not) is reproduced, the oxide is said to be 'reduced.' We have thus two processes inverse to one another—that is, the one undoing what the other does, oxidation and reduction. Thus, there is an important ore of iron called the magnetic oxide of iron; when this is smelted, the oxygen is taken from it, and we obtain metallic iron—this is a process of reduction. If we heat iron strongly in the air, it becomes covered with a crust or scale of a black, brittle substance, which breaks off when the iron is hammered—this is an oxide of iron, and is identical in composition with the magnetic iron ore—this is a process of oxidation. It is obvious that these two processes go in opposite directions.

Most processes of oxidation are accompanied by the giving out of heat, sometimes in a very marked degree; thus, when charcoal is strongly heated in air or oxygen (and it must be remembered that about one-fifth of the atmospheric air consists of oxygen), it unites with oxygen, forming an oxide (carbonic acid, Black's fixed air), and in doing so, gives out much heat. Such an oxidation we call a combustion, or burning. And although different processes of oxidation are accompanied by the giving out of very different quantities of heat, we may generalise the term, and call all such processes cases of 'burning.' Similarly, all processes of reduction may be grouped together as cases of unburning.*

As in a case of 'burning' or 'oxidation,' heat is given out, so in a case of 'unburning' or 'reduction,' heat disappears, or is used up; and we find that exactly as much heat is used in effecting the unburning of an oxide as was given out in producing it. It will thus be seen that the greater

* This is here stated generally; some of the few exceptions will be mentioned among the compounds of Chlorine and Oxygen.

the quantity of heat given out during an oxidation, the greater is the amount of *work* required to be done, in order to effect the corresponding reduction. Now, the difficulty of undoing a union, or of breaking up a combination, may be taken as a measure of its stability, so that the most stable oxides are those during the formation of which the most heat is given out.

Many oxidations can be effected directly by the action of oxygen, and some reductions can be effected directly by means of heat or electricity; thus, hydrogen unites with oxygen, or is burnt, producing water; and water can be decomposed by heat or by electricity into hydrogen and oxygen. There are, however, many oxidations which cannot be effected by the direct action of oxygen, but require the use of an 'oxidising agent'—that is, a substance or mixture containing oxygen in combination, and ready to part with it to a body capable of being oxidised. Thus, nitric acid contains a large quantity of oxygen, and readily gives up part or all of this oxygen to oxidisable substances; accordingly, nitric acid is a powerful oxidising agent, and is used to oxidise bodies in cases where the action can either not be produced at all, or not so conveniently by oxygen alone. As an instance of an oxidising agent which is a mixture, we mention the mixture of chlorine and water. This mixture will oxidise in many cases in which water alone would be without action—the tendency of chlorine to unite with the hydrogen of the water increasing the readiness of the oxygen to leave the hydrogen, and unite with the substance to be oxidised.

Just as we have oxidising agents, so we have also reducing agents—that is, substances or mixtures which remove oxygen: these are generally bodies having a tendency to combine with oxygen, in other words, they are oxidisable; and the most powerful reducing agents are, as might be expected, those which give out most heat in uniting with oxygen. By far the most practically important reducing agents are hydrogen and carbon, either singly as hydrogen gas, and as charcoal or coke, or combined, as they are in coals, coal-gas, wood, and other ordinary combustibles. A large number of metallurgical operations are cases of reduction, in which coal, or coke or charcoal, is used to take away the oxygen of a metallic oxide, and leave the metal uncombined. It is in this way, as is more fully explained in the article METALLURGY, that iron, tin, zinc, and some other metals are reduced from such of their ores as contain the metals as oxides.

THE DOCTRINE OF EQUIVALENTS, AND THE ATOMIC THEORY AND NOTATION.

We have already seen what is meant by an 'equivalent' of an acid, or of a base; we shall now consider the question of 'equivalence' somewhat more fully. As has been already stated, zinc can turn copper out of a salt, such as sulphate of copper, and take its place; this is technically called 'replacement,' and zinc is said to 'replace' copper.* As the salts may be considered as compounds of sulphuric acid (anhydrous) with oxide of copper and with oxide of zinc respectively, it is evident that equivalents of these oxides contain the same quantity of oxygen, for the oxygen remains as it was, thus:

$$\begin{array}{l} \overbrace{\text{Before......Copper}}^{\text{Oxide of Copper.}} \\ \underbrace{\text{After.........Zinc}}_{\text{Oxide of Zinc.}} \end{array}\Big\}\ \text{and Oxygen and Sulphuric Acid.}$$

And in the same way it may be shewn, by means of other replacements, that an equivalent of any basic oxide contains the same quantity of oxygen. By an extension of the meaning of the word equivalent, this quantity of oxygen is called an equivalent of oxygen, and the quantity of metal united to it is called an equivalent of the metal. Those metals which form more than one basic oxide have, of course, more than one equivalent; and when we speak of *the* equivalent of a metal of this kind, we must state *which* basic oxide or which set of salts we are referring to. Thus, the black oxide of mercury contains twice as much mercury as the red oxide for the same quantity of oxygen; and therefore the equivalent of mercury in the black oxide and its salts is twice as great as the equivalent of mercury in the red oxide and its salts. The phenomena of 'electrolysis' furnish an excellent illustration of the equivalence of metals in their salts. When an electric current from a galvanic battery is passed through a solution of a salt, the salt is decomposed, the *metal* being deposited at the end of the wire coming from the zinc of the battery, and the *salt-radical* at the end of the wire coming from the copper of the battery.* This decomposition, by means of an electric current, is called 'electrolysis.' Now, a very remarkable law of electrolysis is, that *a given amount of electricity decomposes (or electrolyses) equivalent quantities of different salts.* Thus, if a current from a battery be made to pass through a series of vessels, each vessel containing a solution of a salt, the quantity decomposed of any one salt will be equivalent to the quantity decomposed of any other. If, now, one of these vessels contain a solution of a salt of the red oxide of mercury, and another a solution of a salt of the black oxide of mercury, we shall find that twice as much mercury is separated in the second as in the first.

In order to express these equivalent quantities in numbers, it is necessary, in the first place, to fix upon a number which shall, by convention, represent one of them, and then, by experiment, find out the relation between the equivalent of that substance and the equivalent of every other element, radical, or substance. For this purpose, it has been found most convenient to select hydrogen as the element with which to compare all others, and to fix the equivalent of hydrogen as unity. The equivalent of hydrogen is thus settled by convention to be 1, and by experiment we determine the equivalents of other elements or radicals. Thus, when hydric sulphate (hydrated sulphuric acid) acts on metallic zinc, for every

* 'Replace' is here used in the sense of the French *remplacer*, and not in its ordinary English sense; but as we have no one English word which can be used to mean 'to be a substitute for,' it seems better to keep the word at present in use, than to try another, such as 'displace' (as has been suggested), which expresses the meaning no better.

* Where the metal is one which acts on water (such as sodium), we have, of course, not the metal itself separated, but the products of its action on water; and similarly if the salt-radical is incapable of separate existence, we obtain the products of its decomposition.

grain of hydrogen set free we find that 32·5 grains of zinc are dissolved, and that, therefore, the *equivalent* of zinc is 32·5. Again, when sulphate of copper acts on metallic zinc, for every 32·5 grains of zinc dissolved we find that 31·75 grains of copper are separated—therefore, the equivalent of copper is 31·75. Once more, when nitrate of silver acts on metallic copper, for every 31·75 grains of copper dissolved we find that 108 grains of silver are separated; therefore, 108 is the equivalent of silver. Now, one grain of hydrogen unites with 8 grains of oxygen to form 9 grains of water; 32·5 grains of zinc unite with 8 grains of oxygen to form 40·5 grains of oxide of zinc; 31·75 grains of copper and 108 grains of silver unite each with 8 grains of oxygen to form respectively 39·75 grains of black oxide of copper and 116 grains of oxide of silver; therefore, the equivalent of oxygen is 8. In the same way, 1 grain of hydrogen, 32·5 grains of zinc, 31·75 grains of copper, and 108 grains of silver unite with 35·5 grains of chlorine to form respectively hydrochloric acid (hydric chloride), chloride of zinc (zincic chloride), chloride of copper (cupric chloride), and chloride of silver (argentic chloride); therefore, the equivalent of chlorine is 35·5.

In a similar way, the equivalent of any element or radical may be determined, it being always recollected that an element or radical has as many different equivalents as it forms series of compounds. Now, if we compare the different equivalents of the same element or radical, we find that they have a simple arithmetical relation to one another. Thus (taking the equivalent of hydrogen as 1), the equivalent of mercury in the red oxide of mercury and in its salts is 100; in the black oxide of mercury and in its salts, 200—that is, twice 100: the equivalent of copper in the black oxide of copper and in its salts is 31·75; in the red oxide of copper and in its salts, 63·5—that is, twice 35·75: the equivalent of iron in the ferrous salts is 28; in the ferric salts, 18·6—that is, two-thirds of 28.

These two facts—1st, that the equivalent of an element remains the same through a series of compounds; and 2d, that the different equivalents of the same element have a simple arithmetical relation to each other—enable us to form a system of chemical notation by means of which the composition of compounds may be fully and distinctly expressed.

In this system of notation, which is known as the ATOMIC NOTATION, certain symbols are used, each of which represents a definite quantity of a particular element. The subjoined table contains the names of the elements with the symbol of each, and the quantity of the element which the symbol represents. This quantity is called the 'atomic weight' of the element, for reasons which will be afterwards stated.

TABLE OF ELEMENTS WITH THEIR SYMBOLS AND ATOMIC WEIGHTS.

Aluminium	Al	27·5
Antimony or Stibium	Sb	122
Arsenicum	As	75
Barium	Ba	137
Beryllium or Glucinum	G	9·3
Bismuth	Bi	210
Boron	B	11
Bromine	Br	80
Cadmium	Cd	112
Cæsium	Cs	133
Calcium	Ca	40
Carbon	C	12
Cerium	Ce	92
Chlorine	Cl	35·5
Chromium	Cr	52
Cobalt	Co	59
Copper (*Cuprum*)	Cu	63·5
Didymium	Di	96
Erbium	Er	112·6
Fluorine	F	19
Gallium	Ga	68
Gold (*Aurum*)	Au	196
Hydrogen	H	1
Indium	In	113
Iodine	I	127
Iridium	Ir	197
Iron (*Ferrum*)	Fe	56
Lanthanum	La	92
Lead (*Plumbum*)	Pb	207
Lithium	Li	7
Magnesium	Mg	24
Manganese	Mn	55
Mercury (*Hydrargyrum*)	Hg	200
Molybdenum	Mo	96
Nickel	Ni	59
Niobium	Nb	97·5
Nitrogen	N	14
Osmium	Os	199
Oxygen	O	16
Palladium	Pd	106·5
Phosphorus	P	31
Platinum	Pt	197
Potassium or Kalium	K	39
Rhodium	Ro	104·3
Rubidium	Rb	85
Ruthenium	Ru	104·2
Selenium	Se	79·5
Silicon	Si	28
Silver (*Argentum*)	Ag	108
Sodium or Natrium	Na	23
Strontium	Sr	87·5
Sulphur	S	32
Tantalum	Ta	138
Tellurium	Te	129
Thallium	Tl	204
Thorium	Th	119
Tin (*Stannum*)	Sn	118
Titanium	Ti	50
Tungsten or Wolfram	W	184
Uranium	U	120
Vanadium	V	51·2
Yttrium	Y	61·5
Zinc	Zn	65
Zirconium	Zr	89·5

If we compare the *atomic weights* as given in this table with the *equivalents* of the elements, we shall find that, even in the cases where each element has only one equivalent, that number has not always been chosen as the atomic weight of the element. Thus, the equivalent is the same as the atomic weight in the case of hydrogen, of potassium, of sodium, of rubidium, of cæsium, and of lithium. But the atomic weight is twice the equivalent in the case of barium, of beryllium, of cadmium, of calcium, of magnesium, of oxygen, of strontium, and of zinc. Aluminium has only one equivalent, and the atomic weight of aluminium is three times its equivalent. Where an element has more than one equivalent, the atomic weight is sometimes equal to one of these equivalents, and sometimes not. Thus, the atomic weight of copper is equal to the equivalent of copper in the cuprous compounds (red oxide of copper and its

salts); the atomic weight of mercury is equal to the equivalent of mercury in the mercurous compounds (black oxide of mercury and its salts); the atomic weight of silver is equal to the equivalent of silver in all its compounds except the peroxide, and the suboxide and the few salts derived from it, &c. The atomic weight of iron is twice the equivalent of iron in the ferrous salts, and three times the equivalent of iron in the ferric salts. In all cases, however, the atomic weight stands in a simple arithmetical relation to each of the equivalents.

The way in which this notation is used will be most easily explained by a few examples. Compound substances are represented by formulæ expressing the proportions by weight of their elementary constituents—thus, HCl means the compound of 1 part by weight* of hydrogen and 35·5 parts by weight of chlorine—that is, 36·5 parts of hydrochloric acid. Here the proportion in which the two elements combine is that of their atomic weights, and the symbols are simply placed one after the other. Again, H_2O means the compound of 2 parts by weight of hydrogen and 16 parts by weight of oxygen—that is, 18 parts of water. Here H_2 represents twice the quantity of hydrogen represented by H, so that as H stands for 1 part of hydrogen, H_2 stands for 2 parts of hydrogen. Again, sulphurous acid gas contains equal weights of sulphur and oxygen, and is represented by the formula SO_2, by which we mean the compound of 32 parts of sulphur and twice 16 parts of oxygen—that is, 64 parts of sulphurous acid gas. In the same way, SO_3 means the compound of 32 parts of sulphur and three times 16 parts of oxygen, and this is 80 parts of anhydrous sulphuric acid. CuO means the compound of 63·5 parts of copper and 16 parts of oxygen—that is, 79·5 parts of black oxide of copper, or cupric oxide. Now, 18 parts of water unite with 80 parts of anhydrous sulphuric acid to form 98 parts of hydrated sulphuric acid (hydric sulphate). Similarly, 79·5 parts of black oxide of copper unite with 80 parts of anhydrous sulphuric acid to form 159·5 parts of cupric sulphate. These compounds may therefore be represented by the complex formulæ H_2O,SO_3 and CuO,SO_3 respectively; the comma placed between the formulæ indicating that the compounds may be regarded as composed, the one of water and anhydrous sulphuric acid, the other of cupric oxide and anhydrous sulphuric acid. Further, if we place cupric sulphate, which is a white powder, in water, 159·5 parts of it at once unite with 18 parts of water, forming a blue powder, which may be represented by the formula CuO,SO_3,H_2O. This blue powder dissolves readily in water, forming a blue solution; and if we evaporate the water carefully, we obtain blue crystals, containing, in addition to the water previously in the blue powder, four times 18 parts of water—the crystalline substance (crystallised cupric sulphate, or blue vitriol) has therefore the formula $CuO,SO_3,H_2O,4H_2O$. Here $4H_2O$ means four times 18 parts of water (a large figure placed *before* a formula multiplying the whole formula up to the first comma). The water present in this salt occurs in two different forms of combination—1. Water of crystallisation, easily driven off by heat; of this there are four molecules. 2. Water retained with great force, requiring a high temperature to expel it, and called 'water of halhydration;' of this there is one molecule. In the same way, hydrated nitric acid, nitrate of potash, and nitrate of copper are represented by the formulæ H_2O,N_2O_5; K_2O,N_2O_5; CuO,N_2O_5 respectively, and crystallised nitrate of copper by $CuO,N_2O_5,3H_2O$. Again, 1 part of hydrogen unites with 35·5 parts of chlorine to form 36·5 parts of hydrochloric acid (or hydric chloride), and this is represented by the formula HCl; and similarly, chloride of sodium (sodic chloride, common salt) and cupric chloride have the formulæ NaCl and $CuCl_2$ respectively. Looking over these formulæ,

Hydrated Sulphuric Acid	or	Hydric Sulphate	H_2O,SO_3,
Sulphate of Soda	"	Sodic Sulphate	Na_2O,SO_3,
Sulphate of Copper	"	Cupric Sulphate	CuO,SO_3,
Hydrated Nitric Acid	"	Hydric Nitrate	H_2O,N_2O_5,
Nitrate of Potash	"	Potassic Nitrate	K_2O,N_2O_5,
Nitrate of Copper	"	Cupric Nitrate	CuO,N_2O_5,
Hydrochloric Acid	"	Hydric Chloride	HCl,
Chloride of Sodium	"	Sodic Chloride	NaCl,
Chloride of Copper	"	Cupric Chloride	$CuCl_2$,

we at once see that 2 parts of hydrogen (H_2), twice 23—that is, 46 parts of sodium (Na_2), 63·5 parts of copper (Cu), and twice 39—that is, 78 parts of potassium (K_2), are equivalent to one another—that is, are capable of playing the same part in a compound.

The reader will remember that salts can be represented not only, as has been done above in the case of the sulphates and nitrates, as compounds of base and acid (anhydrous), but also as compounds of metal and salt-radical, the salt-radical consisting of the anhydrous acid and the oxygen of the base. A glance at the formulæ of the sulphates and nitrates given in the preceding table will shew how this view can be represented by formulæ. Thus:

Hydric Sulphate	H_2O,SO_3	or	H_2,SO_4.
Sodic Sulphate	Na_2O,SO_3	"	Na_2,SO_4.
Cupric Sulphate	CuO,SO_3	"	Cu,SO_4.

Here SO_4 represents the salt-radical of the sulphates—that is, the group of elements which is united with a metal to form a sulphate. This, like many other radicals, cannot be (or at least has not as yet been) obtained as a separate substance, but may still be spoken of and reasoned about as *that which is common to all the sulphates*, that group which remains unchanged when we pass from one sulphate to another. Similarly, we may represent the nitrates thus:

Hydric Nitrate	H_2O,N_2O_5	or	H_2,N_2O_6.
Potassic Nitrate	K_2O,N_2O_5	"	K_2,N_2O_6.
Cupric Nitrate	CuO,N_2O_5	"	Cu,N_2O_6.

Here N_2O_6 is the salt-radical of the nitrates. But it will be at once observed that N_2O_6 can be divided by two, or that N_2O_6 is the same as $2NO_3$; we can therefore simplify the above formulæ thus: Hydric Nitrate, H,NO_3; Potassic Nitrate, K,NO_3; and Cupric Nitrate, $Cu,2NO_3$ or $Cu,(NO_3)_2$ (the group NO_3 between the brackets being multiplied as a whole by the small figure placed after it; in other words, a group of symbols placed within brackets is treated as a single symbol).

* Instead of 'part by weight' or 'part,' we may here and throughout read 'grain,' or 'ounce,' or 'pound,' or any other unit we please; we must, however, remember that, having once adopted a particular unit, we must adhere to it through all the formulæ which we wish to compare together.

We can now compare the formulæ of the sulphates and nitrates with those of the chlorides:

Hydric Sulphate, H_2,SO_4; Hydric Nitrate, H,NO_3; Hydric Chloride, H,Cl.
Sodic Sulphate, Na_2,SO_4; Sodic Nitrate, Na,NO_3; Sodic Chloride, Na,Cl.
Cupric Sulphate, Cu,SO_4; Cupric Nitrate, $Cu,(NO_3)_2$; Cupric Chloride, Cu,Cl_2.

This comparison shews that NO_3 is equivalent to Cl, while SO_4 is equivalent to Cl_2, just as K is equivalent to H, and Cu equivalent to H_2, or that there is a difference in the *value* of the symbols of the salt-radicals in our system of notation, similar to the difference in the *value* of the symbols of the metals. We shall see by-and-by why the atomic weights have been fixed so as to give rise to these differences; our object at present is to explain the use of the system as it is, not to give reasons why it has been made so. It is also obvious that the quantities of the salts above mentioned represented by the last formulæ are not equivalent to one another; the *equivalent* quantities being H_2,SO_4; Na_2SO_4; Cu,SO_4; $2[H,NO_3]$; $2[Na,NO_3]$; $Cu,(NO_3)_2$; $2[H,Cl]$; $2[Na,Cl]$; Cu,Cl_2.

It is of the utmost importance that symbols or formulæ should *always* be used as representing definite *quantities* of the substances, and that the slovenly habit should be avoided of using them as contractions or synonyms for the *names* of the substances. When we use the words 'water,' 'common salt,' or 'sulphate of potash,' we do not indicate any particular quantities of these bodies; but when we write H_2O, NaCl, or K_2SO_4, we mean 18 parts of water, 58·5 parts of common salt, or 174 parts of sulphate of potash. Just as the quantity of an element represented by its symbol is called its atomic weight, so the quantity of a substance represented by its formula is called its molecular weight.

Acids such as hydrochloric and nitric, which contain in one molecule *one* atom of hydrogen capable of being replaced by metal, are called 'monobasic acids;' those that, like sulphuric acid, contain in one molecule *two* such hydrogen atoms, are called 'dibasic acids.' There are also 'tribasic' and 'tetrabasic' acids, containing respectively three and four atoms of replaceable hydrogen. All acids containing in one molecule more than one atom of replaceable hydrogen are called 'polybasic;' and this polybasic character explains the occurrence of acid and double salts of such acids. Thus, in bisulphate of potash, K_2O,SO_3, H_2O,SO_3, or $HKSO_4$, we have *one* of the hydrogen atoms of sulphuric acid, H_2SO_4, replaced by potassium. Again, common phosphoric acid (p. 326) has the formula $3H_2O,P_2O_5$, or H_3PO_4, and is tribasic, so that we have such salts as Ag_3PO_4, Na_2HPO_4, NaH_2PO_4, $NaNH_4HPO_4$, &c.

We can use formulæ not only to express the quantitative composition of substances, but also the action of substances upon each other, or generally, chemical changes. We do this by means of what are called 'chemical equations.' Let us take as an instance the action of sulphate of potash upon chloride of barium. Here we have 174 parts of sulphate of potash and 208 parts of chloride of barium before the change, and after it we have 233 parts of sulphate of baryta and 149 parts of chloride of potassium. We represent the change by the following equation:

$$K_2SO_4 + BaCl_2 = BaSO_4 + 2KCl.$$

The formulæ representing the quantities of the substances before the change are written first, connected by the sign + (which here is the same as '*and*'); then we write = which here stands for '*become*,' or '*are changed into;*' and lastly, the formulæ representing the quantities of the substances produced by the change, also connected by the sign +.

The above equation may then be read as follows: 174 parts of sulphate of potash and 208 parts of chloride of barium are changed into 233 parts of sulphate of baryta and 149 parts of chloride of potassium. We shall have frequent occasion to use such equations farther on in this paper.

The system of atomic or symbolic notation, which we have just explained, originated in the Atomic Theory of Dalton. According to this theory, matter is composed of exceedingly minute ultimate particles or atoms which are incapable of being divided. All the atoms of a given element are precisely similar to one another, but the atoms of one element differ not only in properties, but also in weight, from those of the others; and although we cannot discover the actual weight of an individual atom, the theory assumes that we can discover the proportion existing between the weights of the atoms of different elements, and that these proportions are represented by the atomic weights. Thus, we do not know the weight of an atom of iron, but, if this assumption is correct, it is four times the weight of an atom of nitrogen—that is, in the proportion 56 : 14. In the same way, an atom of mercury is two hundred times as heavy as an atom of hydrogen; and so on.

The theory further supposes that when combination takes place, the atoms of the constituents go together to form groups or molecules; thus, when copper is heated in oxygen, each atom of copper attaches itself to one atom of oxygen to form a molecule of cupric oxide. The formula of a compound may thus be considered as a list of the number and kind of the atoms forming the molecule of the compound.

So far we have considered the proportions *by weight* in which constituents occur in compounds; we shall now look for a little at another way of measuring them—namely, by volume or bulk. We can measure the volume or bulk of a quantity of matter, whether it be solid, liquid, or gaseous, and express it by means of units; and just as we used the word 'part' to indicate a unit of *mass* (which may be a grain, or a pound, or a ton), so now we use the word 'volume' to indicate a unit of bulk (which may be a cubic inch, or a cubic foot, or a gallon), only reminding the reader that here, as before, having once fixed *which* of these is to be our unit, we must adhere to it throughout.

Chemists have made some progress towards finding out the laws of combination according to volume in the cases of solids and liquids; but this part of the subject is at present both too complicated and too speculative to be profitably discussed here. We shall therefore confine ourselves to the laws of combination of gases according to volume. The first step towards the discovery of these laws was made by Gay-Lussac, soon after the publication of Dalton's Atomic Theory; and it is a remarkable fact in the history of chemistry that Dalton, who had thrown so

much light on the laws of combination according to weight, was inclined to doubt the accuracy of Gay-Lussac's views. These views were afterwards greatly extended and simplified by Avogadro; and subsequent investigation and comparison have established what we may call 'Avogadro's law' so fully, that it may be said to be as important a corner-stone of the chemical edifice as the Atomic Theory itself. Without entering into historical questions, which are beyond the scope of this paper, we shall state this law, as it is at present held by the great majority of chemists, thus: *A volume of any gas contains the same number of* molecules *as the same volume of any other gas, the two volumes being measured at the same temperature and pressure.* (See foot-note, p. 311.)* It follows at once from this law that the specific gravities of two gases (taken at the same temperature and pressure) are in the same proportion as their molecular weights; and we have thus a means of determining the molecular weight of any substance which either is a gas at ordinary temperatures, or can be, without chemical change, converted into one by the action of heat, by comparing its specific gravity in the gaseous state with the specific gravity (at the same temperature and pressure) of some gas the molecular weight of which is known.

By applying this method, we find that the molecular formula of a substance is not always the formula which most simply represents its composition.

Thus, let us assume that the formula of hydrochloric acid gas is HCl, and therefore its molecular weight 36·5, and from this let us deduce the molecular weight of some other gases. The specific gravity of hydrogen is to the specific gravity of hydrochloric acid almost exactly as 1 : 18·25, or as 2 : 36·5; therefore, if the molecular weight of hydrochloric acid is 36·5, that of hydrogen must be 2, and its formula H_2. Again, the specific gravity of hydrochloric acid is to that of nitrogen almost exactly as 36·5 : 28; therefore, the molecular weight of nitrogen is 28, and its formula N_2. In these cases, then (and the same is true of many other gases), the theory leads us to believe that the atoms are united in pairs, each pair being a molecule, and that, just as in hydrochloric acid each hydrogen atom is united with an atom of chlorine, so in hydrogen gas each atom of hydrogen is united with another atom of hydrogen. Again, the well-known substance benzol is a compound of carbon and hydrogen in the proportion of 12 parts of carbon to 1 of hydrogen; the simplest formula by which its composition could be represented is obviously CH. If this were its true formula, the specific gravity of its vapour should stand to that of hydrochloric acid gas (at the same temperature and pressure) as 13 : 36·5, but we find the proportion almost exactly 78 : 36·5—that is, 6 times 13 : 36·5. The molecular weight of benzol is therefore 6 times 13, and its formula C_6H_6. In considering individual substances, we shall meet many such cases, and need not, therefore, dwell longer on the subject here.

THE DOCTRINE OF ATOMICITY.

In order to illustrate what is called 'the Doctrine of Atomicity,' we shall give in a tabular form the molecular formulæ of a number of substances, selected so as to place this 'doctrine' before the reader in the way in which it may be most easily understood:

Hydrochloric Acid	HCl.	Water	H_2O.	Ammonia	NH_3.	Marsh Gas	CH_4.
Hydrobromic Acid	HBr.	Sulphuretted Hydrogen	H_2S.	Phosphuretted Hydrogen	PH_3.	Siliciuretted Hydrogen	SiH_4.
Hydriodic Acid	HI.	Seleniuretted Hydrogen	H_2Se.	Arseniuretted Hydrogen	AsH_3.	Perchloride of Tellurium	$TeCl_4$.
Chloride of Sodium	NaCl.	Chloride of Calcium	$CaCl_2$.	Chloride of Gold	$AuCl_3$.	Perchloride of Tin	$SnCl_4$.
Bromide of Potassium	KBr.	Bromide of Zinc	$ZnBr_2$.	Terbromide of Phosphorus	PBr_3.	Bromide of Platinum	$PtBr_4$.

Looking at these formulæ, the reader will easily see that there are some elements, such as hydrogen, chlorine, bromine, iodine, sodium, and potassium, which unite with one another two and two to form compounds containing two atoms in the molecule, one of the one, the other of the other element. Such elements are called 'monads.' Again, there are elements, such as oxygen, sulphur, selenium, calcium, and zinc, which unite with monads to form compounds containing three atoms in the molecule, one atom of the element in question uniting with two monad atoms (as in the second column). Such elements are called dyads. Further, we have elements, such as nitrogen, phosphorus, arsenic, and gold, each atom of which unites with three monad atoms to form a molecule. Such elements are called triads. In the same way there are elements, such as carbon, silicon, tin, and platinum, which are called tetrads, each atom uniting with four monad atoms to form a molecule. These different modes of combination can be represented graphically by drawing lines uniting the symbols of the atoms forming the molecule, thus:

Hydrochloric Acid. Water. Ammonia. Marsh Gas.

Bromide of Sodium. Chloride of Calcium. Terchloride of Phosphorus. Stannic Chloride.

In these *graphic formulæ* it will be observed that a monad atom is represented by its symbol with *one* line proceeding from it; similarly, *two* lines proceed from the symbol of a dyad atom; *three*, from that of a triad; and so on.

The property of combining with a definite number

* This law is in complete accordance with the 'Dynamical Theory of Gases,' as at present held by physicists.

of monad atoms is termed 'atomicity;' thus, the atomicity of hydrogen is one; of oxygen, two; of nitrogen, three; of carbon, four. More complex compounds can be represented in a similar way, thus:

Lime.	Carbonic Acid.	Carbonate of Lime.
$Ca{=}O$	$O{=}C{=}O$	$Ca\begin{matrix}\text{—O—}\\ \text{—O—}\end{matrix}C{=}O$

Chemists are divided in opinion, as to whether an element always has the same atomicity—some holding that this is the case; while others consider that an element may have one atomicity in one set of compounds, and another in another set. The latter school regard, for instance, sulphur as dyad in sulphuretted hydrogen ($H{-}S{-}H$) and analogous compounds, tetrad in anhydrous sulphurous acid (SO_2; $O{=}S{=}O$), and hexad in anhydrous sulphuric acid (SO_3; $O{=}\overset{\overset{\displaystyle O}{\|}}{S}{=}O$) and the sulphates, such as sulphate of potash (K_2SO_4; $K{-}O{-}\underset{\underset{\displaystyle O}{\|}}{\overset{\overset{\displaystyle O}{\|}}{S}}{-}O{-}K$). For further developments of the *Theory of Atomicity*, the reader is referred to any of the larger treatises on chemistry.

DULONG AND PETIT'S LAW.

We have hitherto considered the *atomic weight* of an element as a number adopted merely with a view to the simple, consistent, and convenient representation of the composition of the compounds of that element by means of formulæ. It has been found, however, that the atomic weights so selected have an important relation to some of the physical properties of the elements. The relation of the atomic weight to the *specific heat* (see NATURAL PHILOSOPHY, p. 205) of the elements has been most fully worked out, and will alone be considered here. This relation is expressed by means of a proposition, called, from its discoverers, *Dulong and Petit's Law.* This is, that the specific heat of an element in the solid state is inversely proportional to its atomic weight; or, that the product of the atomic weight and specific heat in the solid state of an element is constant. This law is not absolutely true. The specific heat in the solid state of an element multiplied by its atomic weight is a number which, in the case of the great majority of elements, is 6·6, or very nearly this number, and this enables us in some cases to fix the atomic weight of an element where purely chemical evidence is doubtful; but as there are a few exceptional cases, and as even in those in which the product approximates to 6·6 the divergence is considerable, this law can only be regarded as an indication of a relation, not as an exact statement of it; it is, however, too important to be altogether passed over in such a sketch of chemical principles as we have here endeavoured to give.

We have now gone over the main points of chemical principle: in order to give the reader a general view of the science, it is now necessary that we should append a short statement of chemical *facts*, to supplement what has necessarily been interwoven into the preceding parts of this paper.

SHORT STATEMENT OF THE PROPERTIES OF THE ELEMENTS AND THEIR COMPOUNDS, OF THE METHODS OF PREPARING THEM, AND THEIR ACTION UPON EACH OTHER.

OXYGEN.—Oxygen is a colourless, tasteless, odourless gas; its specific gravity (that of air being taken as unity*) is 1·1056. It is slightly soluble in water, 100 volumes of water, at ordinary temperatures and pressure, dissolving about 3 volumes of oxygen. It has not been reduced to the liquid state by any amount of pressure even at the lowest temperature hitherto attained.

It exists *free* in atmospheric air, of which it constitutes, by volume, about 20·9 per cent. It may be obtained pure—

1. By heating certain metallic oxides, such as oxide of silver (Ag_2O), oxide of mercury (HgO), which simply decompose into oxygen and metal; or peroxide of manganese (MnO_2), peroxide of barium (BaO_2), anhydrous chromic acid (CrO_3), which decompose into oxygen and an oxide of the metal containing less oxygen than the original substance—peroxide of manganese yielding oxygen and an oxide having the formula Mn_3O_4, containing two-thirds of the oxygen in the peroxide—peroxide of barium and anhydrous chromic acid losing half their oxygen, and leaving oxides having the composition expressed by the formulæ BaO and Cr_2O_3 respectively.

2. By the decomposition by heat of certain salts containing oxygen. The most practically important of these are: (*a*) *Chlorate of potash*, K_2O,Cl_2O_5 or $KClO_3$—this salt, when *strongly* heated alone (or by the action of a more moderate heat when mixed with a small quantity of peroxide of manganese, red oxide of iron, or black oxide of copper), decomposing into oxygen and chloride of potassium (KCl), thus yielding all its oxygen as oxygen gas; (*b*) *Sulphate of zinc*, ZnO,SO_3 or $ZnSO_4$, which, when heated, yields oxide of zinc (ZnO), sulphurous acid gas (SO_2), and oxygen gas. As sulphurous acid gas is readily soluble in water, we can obtain the oxygen pure by washing the mixed gas.

3. By the *electrolysis* of water. See p. 311.

4. By the action of the green parts of living plants upon carbonic acid gas and water, under the influence of sunlight. This action cannot be conveniently used for the preparation of pure oxygen, but it plays a most important part in the economy of nature. See VEGETABLE PHYSIOLOGY.

Oxygen is a *supporter of combustion;* that is, it enters into combination with combustible substances, and in doing so produces a great deal of heat. The conditions under which such combustions take place, and the products formed, will be given under the heads of the combustible substances themselves.

Oxygen is essential for the support of *animal life.* In the process of respiration, oxygen is absorbed by air-breathing animals in the lungs, by water-breathing animals in the gills from the oxygen dissolved in the water, in both cases the red colouring-matter of the blood entering into a feeble combination with oxygen. Oxygen is thus carried by the blood to all parts of the body, where

* Throughout this paper, when it is not otherwise stated, the specific gravity of a gas is referred to that of air as unity.

it combines with the carbon and hydrogen of the tissues, producing carbonic acid and water. This combination is attended by the evolution of heat, and is thus the source of animal heat. See HUMAN PHYSIOLOGY.

The compounds of oxygen have already been to some extent described, and will be further treated of under the elements of which they are oxides. Most common rocks, such as quartz, granite, limestone, trap, basalt, &c. are compounds of oxygen.

Ozone is a remarkable modification of oxygen. It has hitherto been obtained only mixed with a large proportion of common oxygen. Oxygen can be ozonised—that is, part of it converted into ozone —in various ways; for instance, by passing electric sparks through it, or by the slow combustion of various substances, as phosphorus. Oxygen prepared by electrolysis contains ozone. Ozone can be converted into common oxygen by heat, and also by contact with a great variety of substances. Ozonised oxygen occupies less space than the common oxygen from which it was prepared, and expansion takes place when ozone is reconverted into common oxygen, thus proving that ozone is denser than common oxygen. Experiments seem to prove that the density of ozone is to that of common oxygen as 3 : 2. If this is the case, the molecular formula of ozone is O_3, as that of common oxygen is O_2. Ozonised oxygen has a strong and peculiar odour, and acts as a bleaching and oxidising agent. It is generally present in small quantity in the air, and probably is of use in oxidising offensive and injurious organic matters.

HYDROGEN is a colourless, tasteless, odourless gas. Its specific gravity is 0·0693; in other words, 14½ volumes of hydrogen have the same weight as one volume of air. Light balloons filled with hydrogen, therefore, rise in the air. Hydrogen is very slightly soluble in water, 100 volumes of water dissolving less than two volumes of the gas. It has not been reduced to the liquid state.

Hydrogen does not occur free in this planet, but spectroscopic observations (see ASTRONOMY) prove that it exists in large quantity in the atmosphere of the sun. It forms one-ninth part, by weight, of water, and is an essential constituent of all animal and vegetable tissues. It may be obtained—1. By the electrolysis of water, or dilute acids (see p. 311). 2. By the action of water on certain metals —as sodium, at ordinary temperatures, iron or zinc at a red-heat, the metal uniting with the oxygen, and setting the hydrogen free. 3. By the action of some hydrated acids (hydric salts) upon metals—as hydrochloric acid on zinc, iron, or tin; dilute sulphuric acid on zinc or iron; the metal simply replacing the hydrogen (see p. 312).

Hydrogen is inflammable—that is, it can be set fire to in air or oxygen. In order to set fire to it, the contact of a red-hot body is necessary. If a piece of spongy platinum is placed in a mixture of oxygen and hydrogen, the two gases condense in the pores of the platinum, unite there, and produce sufficient heat to render the metal red-hot, and this sets fire to the hydrogen. As already stated (p. 311), two volumes of hydrogen unite with one volume of oxygen to form water. If the two gases are mixed in this proportion, an explosive mixture is formed. When a flame or a red-hot body is applied to such a mixture, very rapid combination takes place, with violent explosion, caused by the sudden evolution of heat. Hydrogen at a high temperature is a powerful reducing agent. By far the most important compound of hydrogen and oxygen is water; its chief chemical properties have already been described.

The only other known compound of these two elements is the *peroxide of hydrogen.* This substance is formed when acids act on peroxide of sodium or peroxide of barium; thus, $BaO_2 + 2HCl = H_2O_2 + BaCl_2$. Its formula is H_2O_2, and it contains hydrogen and oxygen in the proportion of 1 : 16. It decomposes very readily into water and oxygen gas; a very slight rise of temperature is sufficient to effect this decomposition. In many cases it acts as an oxidising agent, because of the readiness with which it gives up half of its oxygen; but, curiously enough, it sometimes acts as a *reducing* agent. Thus, when brought in contact with oxide of silver, it not only gives off its own superfluous oxygen, and is reduced to water, but also, if we may use the expression, induces the oxide of silver to give up its oxygen too, so that metallic silver is produced.

NITROGEN is a colourless, tasteless, odourless gas. Its specific gravity is 0·972; 100 volumes of water dissolve at ordinary temperatures about 1½ volume of the gas; it has not been condensed to the liquid state. Nitrogen occurs in the atmosphere, of which it forms about 79·1 per cent. by volume. Atmospheric air consists essentially of nitrogen and oxygen, with comparatively very small quantities of other gases—carbonic acid, ammonia, and water-vapour. Nitrogen may be prepared from atmospheric air by removing the oxygen; this can be done in various ways; of these we may mention: 1. Passing air through a long tube containing metallic copper, heated to redness; the copper unites with the oxygen, forming cupric oxide, CuO, and the nitrogen passes on. 2. Burning phosphorus (or allowing it slowly to oxidise) in air, the oxygen unites with the phosphorus, forming phosphoric (or phosphorous) acid (see p. 326), which can be removed by water, in which it is soluble.

Nitrogen gas is an eminently inactive substance, and does not readily enter into combination with other elements. In the air, its chief function is to act as a diluent of the oxygen. There are, however, a great many very important compounds of nitrogen which we obtain indirectly from one another. All animals and vegetables contain compounds of nitrogen; and by the decomposition of dead animal and vegetable matters, and from the excreta of animals, other compounds of nitrogen are formed, which in their turn form part of the food of plants. Thus, there is a constant circulation of nitrogen from one state of combination to another, and with this circulation the great mass of free nitrogen in the air has very little connection. We shall here shortly describe the compounds of nitrogen with oxygen and with hydrogen.

Compounds of Nitrogen and Oxygen.—Of these there are five—namely:

Nitric Acid (anhydrous), N_2O_5, forming, with water, hydrated nitric acid or hydric nitrate, H_2O,N_2O_5 or HNO_3; and with bases, nitrates, as K_2O,N_2O_5 or KNO_3, nitrate of potash or potassic nitrate.
Peroxide of Nitrogen, NO_2.
Nitrous Acid (anhydrous), N_2O_3, does not form a stable hydric salt with water, but unites with bases forming nitrites, as K_2O,N_2O_3 or KNO_2, nitrite of potash or potassic nitrite.
Nitric Oxide, NO.
Nitrous Oxide, N_2O.

Nitrates and nitrites occur in the soil. The mode of their formation will be considered under Ammonia. Hydrated nitric acid can be obtained by heating any nitrate (most commonly, nitrate of soda—the cheapest nitrate—is used) with sulphuric acid (see p. 309). All the other oxides of nitrogen are most easily prepared from hydrated nitric acid. Peroxide of nitrogen is a reddish-brown vapour, having an extremely irritating action on the lungs when even a small quantity of it mixed with much air is breathed. It can be condensed to a brown liquid, nearly colourless when cooled to a low temperature. It is formed—1. By the reduction of nitric acid—as when hydrated nitric acid acts on tin, the tin unites with part of the oxygen, forming an oxide; and red fumes are given off, consisting of peroxide of nitrogen. 2. By the decomposition of some nitrates by heat—for instance, nitrate of copper, CuO,N_2O_5, when heated, gives cupric oxide, CuO, which remains behind; while, instead of anhydrous nitric acid being given off, we have peroxide of nitrogen and free oxygen, $CuO,N_2O_5 = CuO + 2NO_2 + O$. 3. By the union of nitric oxide and oxygen. Nitric oxide, NO, when mixed with oxygen, at once combines with it, forming peroxide of nitrogen.

Nitrous acid is produced in various reductions of nitric acid—for instance, when hydrated nitric acid acts on white arsenic, or on starch. It is a reddish-brown vapour, closely resembling peroxide of nitrogen. It can be condensed to a blue liquid. When nitrate of potash, K_2O,N_2O_5 or KNO_3, is strongly heated, it loses oxygen, and yields nitrite of potash, K_2O,N_2O_3 or KNO_2.

Nitric oxide is a colourless, transparent gas, very sparingly soluble in water. It has not been condensed to the liquid state. It is formed by the reduction of nitric acid—for instance, when hydrated nitric acid acts on some metals (copper, lead, mercury, silver), an oxide of the metal is formed, which at once unites with nitric acid to form a nitrate, and nitric oxide gas is given off. Its most remarkable character is its action on oxygen gas. When these two colourless gases are mixed, they instantly combine to form red fumes of peroxide of nitrogen.

Nitrous oxide is a colourless transparent gas, having a sweetish taste. Water, at ordinary temperatures, dissolves about its own volume of the gas. It can be condensed by cold and pressure to the liquid state, and may be frozen to an ice-like solid by very intense cold. This gas supports the combustion of most ordinary combustibles, such as wood, paper, wax, &c. the oxygen combining with the combustible, and the nitrogen becoming free. It cannot, however, support animal life, as the oxygen is too firmly held by the nitrogen to be given up to the red colouring-matter of the blood. At the same time, it is not directly poisonous, and can be breathed for a short time without injury. When so breathed, it produces insensibility, and is now used in minor surgical operations for the same purposes as chloroform or ether. In small quantities, it produces intoxication, whence its popular name, laughing-gas. Its preparation will be described under Ammonia.

The only known substance consisting solely of nitrogen and hydrogen is ammonia. Ammonia is a colourless, transparent gas, having a peculiar pungent odour. Its specific gravity is 0·59. It is very soluble in water, one volume of water absorbing, at ordinary temperatures and pressures, between 600 and 700 volumes of the gas. Solution of ammonia is specifically lighter than water: it gives up the whole of the ammonia when boiled. This solution is what is sold as 'liquor ammoniæ,' or 'spirit of hartshorn.' The gas can be condensed by cold and pressure to a colourless liquid.

Ammonia is composed of 14 parts by weight of nitrogen, and 3 of hydrogen: its formula is NH_3. It unites with the *hydrated* acids or hydric salts to form ammonia salts. Thus, ammonia unites with hydrochloric acid to form the salt known as sal-ammoniac—$NH_3 + HCl = NH_3,HCl$ or NH_4Cl; with nitric acid to form nitrate of ammonia—$NH_3 + HNO_3 = NH_3,HNO_3$ or NH_4NO_3; with sulphuric acid it unites in two proportions to form acid sulphate of ammonia, or bisulphate of ammonia, and normal sulphate of ammonia—$NH_3 + H_2SO_4 = NH_3,H_2SO_4$ or NH_4HSO_4, and $2NH_3 + H_2SO_4 = 2NH_3,H_2SO_4$ or $(NH_4)_2SO_4$. These ammonia salts resemble very closely, in crystalline form and in many chemical characters, the corresponding potash salts; and if we compare the formulæ of the two sets of salts, we see that there is also an analogy in composition:

NH_4Cl;	NH_4NO_3;	NH_4HSO_4;	$(NH_4)_2SO_4$, &c.
KCl;	KNO_3;	$KHSO_4$;	K_2SO_4, &c.

The reader will at once see that wherever we have in a potash salt K (that is, 39 parts of potassium), in the corresponding ammonia salt we have NH_4 (that is, 17 parts of ammonia and 1 of hydrogen). NH_4 is, therefore, a *compound radical* (see p. 313), and stands to K in a relation similar to that of NO_3 to Cl. This compound radical has received the name of ammonium: thus, sal-ammoniac, NH_4Cl, is chloride of ammonium, &c. There are some points where the analogy between potassium and ammonium breaks down. We may compare this analogy to that between a firm or corporation and an individual person. In buying and selling, in borrowing and lending, in suing or in being sued, a corporation or firm resembles an individual; but there are cases where this resemblance totally ceases—those cases, namely, which lead to the dissolution of the firm, or the surrender of the charter of the corporation. So in the case of ammonium and potassium, in a great many double decompositions, the actions of the ammonium salts resemble those of the potassium salts—ammonium (NH_4) in the one case, and potassium (K) in the other, changing place with other metals; but sometimes the ammonium breaks up, and its constituents take each its separate course. It is by a reaction of this kind that pure ammonia is prepared. Anhydrous potash), K_2O, and hydrated or caustic, K_2O,H_2O (or KHO), are compounds of potassium which have no analogues in the ammonium set. There is no $(NH_4)_2O$, and no NH_4HO.* Every chemical change which might be expected to produce either of these bodies really yields ammonia and water—$(NH_4)_2O$ becoming $2NH_3 + H_2O$, and NH_4HO becoming $NH_3 + H_2O$. Thus, when

* The formula NH_4HO and the name hydrated oxide of ammonium are sometimes used, but they do not refer to a definite substance, but merely to ammonia and water acting together.

an ammonia salt—say sal-ammoniac (chloride of ammonium)—is mixed with caustic potash (hydrate of potash), a change takes place, which is represented by the following equation :

$$NH_4Cl + KHO = KCl + NH_3 + H_2O.$$

The K takes the place of the NH_4, but the NH_4 not being able to take the place of the K, breaks up, and instead of NH_4HO, which might have been expected, we have $NH_3 + H_2O$. In preparing ammonia, slaked lime (hydrate of lime) is usually employed instead of caustic potash. The action is quite similar to that given above :

$$2NH_4Cl + CaO,H_2O = CaCl_2 + 2NH_3 + 2H_2O.$$

This operation is conducted in a retort; and the ammonia, if required as a gas, may be dried by passing it through a tube containing fragments of solid caustic potash, which retains the water; or if a solution of the gas (spirits of hartshorn) is wished, it is led into vessels containing water, which dissolves it.

If we attempt to isolate ammonium, it also breaks up, and ammonia and hydrogen are produced. Thus, if sodium amalgam, a compound of sodium and mercury, is covered with a strong solution of sal-ammoniac, the sodium and the ammonium change places, and we obtain chloride of sodium and ammonium amalgam. This, however, rapidly decomposes; hydrogen and ammonia are given off, and mercury remains behind.

The most important source of ammonia and ammoniacal salts is the decomposition of animal and vegetable matters containing nitrogen. Dead animals and vegetables, and animal excreta, yield ammonia in decomposing. When coal (the remains of dead plants) is distilled in the manufacture of gas, a considerable quantity of ammonia is produced, and it is from this source that the ammonia of commerce is chiefly obtained.

The following salts of ammonia deserve notice here. Sulphate, $(NH_4)_2SO_4$, largely used as a manure; sal-ammoniac, NH_4Cl; the nitrate, NH_4NO_3, is specially interesting, on account of the way in which it decomposes when heated, all of the hydrogen uniting with two-thirds of the oxygen to form water, while the nitrogen and the rest of the oxygen form nitrous oxide gas, thus : $NH_4NO_3 = 2H_2O + N_2O$. The nitrite, NH_4NO_2, undergoes a similar decomposition, yielding water and nitrogen gas, $NH_4NO_2 = 2H_2O + N_2$.

It has been stated above that decaying animal and vegetable matters, when these contain, as they generally do, nitrogen, give off ammonia; now, if ammonia, or such ammonia-producing matters are exposed to air in the presence of bases, especially if so exposed in a porous material, such as the soil, the ammonia undergoes oxidation, and in the first place a nitrite is produced, and this nitrite is converted into a nitrate, if the exposure to oxygen is long continued. What nitrite or nitrate is formed depends of course upon the base with which the ammonia was mixed. This is the origin of nitrates in the soil, and thus nitrate of potash is produced in Bengal, where the soil contains potash; nitrate of lime and nitrate of magnesia in this country, where the soil contains these bases. The nitrate of soda, found in extensive layers in Bolivia, appears to have had a different origin. Nitrates and nitrites are not unfrequently found in the water of shallow wells in towns and villages; in such cases, this usually indicates that decaying animal matters, drippings from dunghills, sewage, &c. have percolated through the soil, and found their way, more or less oxidised, into the well.

CARBON occurs free in nature in two perfectly distinct forms : 1. As diamond, a colourless transparent solid, of specific gravity 3·5. It is the hardest substance known; it is found crystallised in forms derived from the cube. When strongly heated in air or oxygen, diamond burns, forming carbonic acid. 2. As graphite, plumbago, or blacklead, a black, opaque solid, with a metallic lustre, crystallised in hexagonal plates. Graphite is seldom found quite pure, generally mixed with from one to five per cent. of iron, silica, and alumina. When strongly heated in air or oxygen, it burns, forming carbonic acid. In combination, carbon is very widely diffused; carbonic acid (CO_2) occurs in atmospheric air in the proportion of about four parts in 10,000. It is poured out in great quantity by volcanos, and from cracks in the earth's surface; many mineral waters contain carbonic acid in solution; it is produced by the combustion and by the slow oxidation (decay) of animal and vegetable substances, all which contain carbon; and forms a large part of the air expired by animals (p. 320). It is also produced in the alcoholic fermentation (see p. 332). Carbonates occur in great quantity in nature; carbonate of lime (marble, limestone, chalk, calcspar), carbonate of lime and magnesia (dolomite, magnesian limestone) being most abundant minerals, and forming the mass of many great mountain chains. Carbonate of iron (p. 329) is one of the most important iron ores. Carbon occurs in nature combined with hydrogen in marsh gas (CH_4), and is an essential constituent of all animal and vegetable tissues. From such tissues carbon may be obtained as *charcoal* by the action of heat. When animal or vegetable substances are heated to redness in such a manner as to exclude air or oxygen from them, the hydrogen and oxygen (and nitrogen and sulphur, if these elements are present) go off with *part* of the carbon as gases or volatile bodies, while the rest of the carbon remains behind as charcoal. This heating or charring may be conducted in either of two ways : 1. The wood, coal, or other substance to be charred, may be set fire to in heaps so arranged that the access of air is limited, only so much being admitted as is necessary to burn a *part* of the combustible, and so furnish heat enough to char the rest. This process is adopted in charcoal-burning in countries where wood is abundant, and in coking-ovens for preparing coke for fuel. 2. By heating the substance to be charred in cylindrical retorts heated by special furnaces outside the retorts; in this process, the gases and volatile matters, instead of being burnt, are led off by pipes from the retorts (see No. 31). Charcoal varies greatly in character according to the substances from which it is prepared; thus, we have wood-charcoal, peat-charcoal, coke (coal-charcoal), bone-charcoal, blood-charcoal, &c. These differ from one another in texture, being more or less dense, more or less porous, &c.; they also contain mixed with them all the mineral matter which may have been present in the substance charred. Nearly every kind of charcoal has a remarkable power of absorbing gases and vapours, and is therefore used for

removing offensive vapours from air; charcoal, especially animal charcoal, also absorbs many colouring-matters, and is accordingly used to decolorise solutions, as in sugar-refining. Charcoal, when heated in air or oxygen, burns, forming carbonic acid.

Lampblack is a form of carbon deposited from the flame of gaseous or volatile compounds of carbon. When compounds of carbon and hydrogen are burnt with a sufficient supply of air or oxygen, the hydrogen is burnt to water, and the carbon to carbonic acid; but if there is not enough oxygen for both, the carbon, or part of it, is deposited as smoke or lampblack. Charcoal and lampblack are 'amorphous;' that is, are not crystalline. We have, then, three distinct forms of the element carbon, two crystalline—diamond and graphite—and one amorphous. These are called 'allotropic' forms of carbon; and carbon is said to be 'dimorphous,' because it occurs in *two* different crystalline forms.

Compounds of Carbon and Oxygen.—Carbonic acid (anhydrous carbonic acid, carbonic anhydride) is composed of carbon and oxygen in the proportion of 3 to 8; its formula is CO_2. It is a colourless transparent gas, and has a pungent taste. Its specific gravity is 1·524. Water dissolves at ordinary temperatures about its own volume of the gas. It can be reduced by cold and pressure to the liquid state, and the liquid can be frozen so as to form a solid. When the gas is produced in a vessel closed at the bottom, such as a brewer's vat or tan-pit (see *Fermentation*, p. 332), or poured from cracks or crevices into a well or mine, it remains—on account of its specific gravity being $1\frac{1}{2}$ time that of air—as a layer at the bottom, only slowly mixing with the air by diffusion (page 306), unless it be disturbed. Loss of life has frequently been caused by persons incautiously descending into such vats or pits, as carbonic acid not only does not support animal life, but is directly injurious. As already mentioned, atmospheric air contains, normally, about 4 parts in 10,000, and this proportion may be considerably increased without serious effects to animal life. Some authors assert, that air which contains one part of carbonic acid in 200 is dangerous; but there is no doubt that when the quantity reaches 2 or 3 per cent. death may be produced. Carbonic acid does not support combustion; a lighted candle is extinguished when plunged into a jar of the gas; it must, however, be remembered that a candle will burn in an atmosphere in which a man could not live, for air containing 2 or 3 per cent. of carbonic acid will support the flame of a candle, but not the life of a man.

Carbonic acid (being an anhydrous acid) unites with bases to form carbonates—as normal carbonate of soda (washing-soda), Na_2O,CO_2 or Na_2CO_3 (this salt crystallises with 10 molecules of water of crystallisation); bicarbonate of soda (baking-soda), Na_2O,CO_2,H_2O,CO_2 or $NaHCO_3$; carbonate of lime (chalk, marble, limestone), CaO,CO_2 or $CaCO_3$. From carbonates we can easily obtain carbonic acid by the action of any strong acid, as hydrochloric acid, and as hydrated carbonic acid does not exist, we obtain by this action anhydrous carbonic acid and water, thus:

$$CaO,CO_2 + 2HCl = CaCl_2 + H_2O + CO_2.$$

Other sources of carbonic acid have already been mentioned.

Carbonic oxide is composed of carbon and oxygen in the proportion 3 : 4—its formula is CO. It is a colourless transparent gas, of specific gravity 0·968, or almost exactly the same as that of nitrogen.* Carbonic oxide is very slightly soluble in water, and has not been liquefied. It may be prepared in various ways; of these we shall mention three. 1. When carbonic acid is passed through a tube containing red-hot iron turnings, the iron takes half of the oxygen from the carbonic acid, and carbonic oxide is produced. 2. When carbonic acid is passed through red-hot charcoal, it takes up carbon—thus $CO_2 + C = 2CO$. This mode of formation may be seen in a common fireplace, in which a clear red fire is burning; the air enters at the bottom of the grate, and its oxygen combines with carbon, forming carbonic acid; this gas passing upwards through the red-hot charcoal or cinders, is converted into carbonic oxide, which burns with a blue flame at the top of the fire. 3. When *oxalic acid* is heated with strong sulphuric acid, it is decomposed into water, carbonic oxide, and carbonic acid, thus:

$$\underset{\text{Oxalic Acid.}}{H_2C_2O_4} = H_2O + CO + CO_2.$$

Carbonic oxide is combustible, burning with a blue flame, and forming carbonic acid. It is an exceedingly poisonous gas, much more so than carbonic acid, and, along with the latter, is the cause of the deaths which have frequently been produced by breathing the air of a room where charcoal has been burnt without a chimney or proper ventilation.

Compounds of Carbon and Hydrogen.—These substances are called 'hydrocarbons,' and form a very large and important class of compounds. When we name as specimens of the class, paraffin oil, solid paraffin, benzine, oil of turpentine, oil of roses, india-rubber, it will be obvious to the reader that it is impossible here to describe the hydrocarbons in detail; some of the more important are treated of in the paper on CHEMISTRY APPLIED TO THE ARTS. We shall here enumerate some of their general characters, and describe two of the simplest hydrocarbons. All hydrocarbons are colourless (when pure), volatile, and combustible; when sufficient oxygen is supplied, they burn to form carbonic acid and water. If the supply of oxygen is insufficient, tarry matters and lamp-black are produced. The luminosity or brightness of the flame depends greatly on the proportion of carbon, the flame being generally brighter the more carbon is contained in the compound.

The two hydrocarbons which we shall here describe are, marsh gas and olefiant gas.

Marsh gas contains carbon and hydrogen in the proportion 3 : 1; its formula is CH_4. Of all known hydrocarbons it contains the largest proportion of hydrogen, and therefore gives the least luminous flame. It is a colourless transparent gas, scarcely soluble in water, and has not been liquefied. Its specific gravity is 0·558. It is the lightest gaseous hydrocarbon, and is often called 'light carburetted hydrogen.' It is produced by the decomposition

* It will be observed that the molecular weight of carbonic oxide is the same as that of nitrogen, $12 + 16 = 2 \times 14$. Their specific gravity should therefore be the same (p. 318). The slight discrepancy is no doubt due to these gases (as is the case with all gases) deviating *slightly*, and not to the same extent, from Boyle's law.

of vegetable matter under water; the gas which bubbles up when the bottom of a pond is disturbed consists of marsh gas mixed with carbonic acid. It also occurs in cavities in coal-seams, and forms the 'fire-damp' of our coal-mines, and is produced by the distillation of many organic substances. It is one of the constituents of coal-gas. It is a combustible gas, and when mixed with the proper proportion of oxygen, forms an explosive mixture. The products of the combination are carbonic acid and water, $CH_4 + 2O_2 = CO_2 + 2H_2O$. From this equation it will be seen that one volume of marsh gas requires two volumes of oxygen for its combustion. As air contains about 20 per cent. of oxygen, one volume of marsh gas requires 10 volumes of air for its complete combustion. The explosions which occur in coal-mines are caused by the ignition of such a mixture, and explosion takes place even when the two gases are not in the exact proportions given above. It has been found by experiment that no explosion takes place when there is less than three volumes, or more than 18 volumes of air, to one of marsh gas. It will be remembered that a red-hot body will cause explosion of a mixture of hydrogen and oxygen—the temperature at which marsh gas takes fire is much higher—contact with a flame or white-hot body being necessary. It is upon this fact that the efficacy of Davy's safety-lamp depends. In this lamp the flame is inclosed in a cylinder of wire-gauze. If such a lamp be placed in an explosive mixture of marsh gas and air, the mixture inside the cylinder, immediately in contact with the flame of the lamp, will burn; but this combustion will not extend to the mixture outside, as the gases, by passing through the meshes of the wire-gauze, are cooled down below the temperature necessary for kindling marsh gas. The enlargement of the flame, due to the marsh gas burning inside the cylinder, is a warning to the miner of the presence of 'fire-damp.'

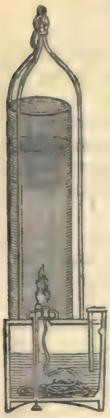


Fig. 2.

Olefiant gas contains carbon and hydrogen in the proportion 6 : 1; its formula is C_2H_4. It is a colourless transparent gas of specific gravity 0·978. It is inflammable, burning with a strongly luminous flame, and producing carbonic acid and water, $C_2H_4 + 3O_2 = 2CO_2 + 2H_2O$. It occurs in coal-gas, and the luminosity of coal-gas is to a great extent due to its presence. It can also be prepared by heating a mixture of four parts of strong sulphuric acid and one of alcohol; the action which takes place is represented by the following equation:

$$\underset{\text{Alcohol.}}{C_2H_6O} = \underset{\text{Water.}}{H_2O} + \underset{\text{Olefiant Gas.}}{C_2H_4}$$

The sulphuric acid in this case acts as a dehydrating or water-removing agent.

CHLORINE has been already spoken of (p. 313) as a simple or elementary *salt-radical*. It occurs in nature in combination with metals, forming metallic chlorides. Of these the most important is chloride of sodium or common salt (NaCl). Common salt is by far the most abundant of the salts dissolved in sea-water, and is obtained from sea-water by spontaneous evaporation in shallow ponds or marshes in the neighbourhood of the sea in warm countries. It also occurs in extensive beds as rock-salt, and in solution in many mineral waters. When acted on by sulphuric acid, it yields sulphate of soda and hydrochloric acid gas ($2NaCl + H_2SO_4 = 2HCl + Na_2SO_4$). Hydrochloric acid gas is a colourless transparent gas, of specific gravity 1·27. It is very soluble in water; at ordinary temperatures, water dissolves about 450 times its volume of the gas. The solution is denser than water, and the gas cannot be wholly expelled by boiling. The solution is generally called hydrochloric acid, or muriatic acid, or spirit of salt. Hydrochloric acid acts upon such metallic oxides as are bases, producing a salt and water; thus, $CaO + 2HCl = CaCl_2 + H_2O$. But if we take an oxide such as peroxide of manganese, which is not a base, and has no corresponding chloride, the action is different, thus: $MnO_2 + 4HCl = MnCl_2 + Cl_2 + 2H_2O$. Instead of obtaining $MnCl_4$, we have $MnCl_2$ *and* Cl_2; that is, free chlorine. It is in this way that chlorine gas is prepared. Chlorine is a greenish yellow gas, of specific gravity 2·45, having a pungent smell. As it is much heavier than air, it may be collected by displacement, the tube from which it issues being led to the bottom of the receiving vessel. The chlorine collects at the bottom of the vessel, and gradually fills it, driving out the air (see fig. 3). It cannot be breathed unless very much diluted with air, and has a very irritating effect on the lining membrane of the air-passages. Water dissolves about twice its volume of chlorine gas. Chlorine unites very readily with hydrogen; a jet of hydrogen kindled in chlorine burns readily, forming hydrochloric acid. A mixture of equal volumes of hydrogen and chlorine can be kept for any length of time in the dark, but explodes violently when exposed to sunlight. In diffused light, the two gases combine more slowly. This tendency of chlorine to combine with hydrogen renders *wet chlorine*, or chlorine along with water, a very powerful oxidising agent; the chlorine attracting the hydrogen of the water, the oxygen of which thus becomes more easily separated, and can therefore readily attack oxidisable substances.

Fig. 3.

It is in this way that chlorine acts as a bleaching and as a disinfecting agent. Many colouring-matters, and many offensive gases and vapours, are oxidisable, and can, by oxidation, be converted into colourless substances, or into inodorous bodies. In these cases, they are destroyed by wet chlorine—the chlorine taking the hydrogen of the water, while the oxygen oxidises the colouring or offensive substances. Chlorine unites with slaked

lime, forming chloride of lime, or bleaching-powder; when sulphuric acid is added to this substance, sulphate of lime is formed, and chlorine is set free.

Chlorine has only a very slight affinity for oxygen, so that the two elements do not directly combine; and their compounds, when indirectly produced, decompose very easily into chlorine and oxygen, the decomposition usually taking place with explosive violence. In these decompositions, heat is given out.

Of these we may mention *Chloric Acid.* Anhydrous chloric acid (Cl_2O_5), corresponding to anhydrous nitric acid (N_2O_5), has not yet been obtained, but many of its salts are well known. Hydrated chloric acid (hydric chlorate, H_2O,Cl_2O_5 or $HClO_3$) is a very explosive and powerfully oxidising liquid. Chlorate of potash (K_2O,Cl_2O_5 or $KClO_3$) is important as a source of oxygen, and as an ingredient in the composition with which some kinds of lucifer-matches are tipped, and in many fireworks.

BROMINE and IODINE are elements closely resembling chlorine in chemical character. They form bromides and iodides with metals, hydrobromic and hydriodic acids with hydrogen, and bromates and iodates corresponding to the chlorates. Their affinity for hydrogen and the metals is in the order chlorine, bromine, iodine; being greatest in the case of chlorine, least in that of iodine. Their affinity for oxygen is in exactly the opposite order; being greatest in the case of iodine, least in that of chlorine.

Bromides occur in small quantity in sea-water and many mineral springs, from the 'mother-liquor' of which (or liquid left after the removal of the less soluble chloride of sodium) bromine is obtained. Compounds of iodine occur in extremely small quantity in sea-water, from which they are removed by sea-weeds. Iodine is obtained from the 'kelp' or ash of such sea-weeds. Bromine is a volatile brown liquid; iodine, a volatile black solid, yielding a beautiful purple vapour when heated.

SULPHUR occurs native in many volcanic districts, most of the sulphur of commerce being obtained from Sicily. It is purified by distillation, and is met with in commerce either as 'flowers of sulphur'—that is, a fine powder produced by rapidly cooling the sulphur-vapour—or as roll-sulphur, cast in cylindrical moulds. When heated, sulphur fuses, at a temperature of about 234° Fahrenheit, forming a mobile liquid of a brownish yellow colour. If this liquid is allowed to cool, it solidifies into an 'allotropic' modification of sulphur. This form of sulphur differs from the usual one: in colour, it is brownish yellow, instead of bright yellow; in specific gravity, it is somewhat lighter than common sulphur; and in crystalline form. When kept, however, it changes back again to the common form. If fused sulphur is heated, it begins to become thick like treacle at a temperature very little above 250° F. The thickness increases as the temperature rises, until, at about 430° F. the vessel containing it can be inverted without any of the sulphur pouring out; about 640° F. it is again more liquid, and can be poured out. If at this stage the sulphur is rapidly cooled by pouring it into water, it is obtained in a plastic form, elastic like india-rubber. This modification, when kept, passes back into the common form of sulphur.

Compounds of Sulphur and Oxygen.—When sulphur is burned in air or oxygen, it unites with oxygen, and forms anhydrous sulphurous acid, a colourless transparent gas, consisting of equal weights of sulphur and oxygen. Its formula is SO_2, its specific gravity is 2·25. It can easily be condensed to a colourless liquid, and dissolves readily in water; one volume of water dissolving about 30 volumes of the gas at ordinary temperatures. The gas has the pungent smell of burning sulphur, and cannot be breathed unless mixed with a large quantity of air. It unites with bases, forming sulphites, such as normal sulphite of soda (Na_2O,SO_2 or Na_2SO_3), acid sulphite of soda (Na_2O,SO_2,H_2O,SO_2 or $NaHSO_3$). Sulphurous acid and the sulphites act as reducing agents (p. 314), taking up oxygen to form sulphuric acid or sulphates. Sulphurous acid acts also as a bleaching agent, rendering certain animal and vegetable colouring-matters colourless, and is used for bleaching straw and woollen goods.

Sulphurous acid is a weak acid, and the sulphites are decomposed by most strong acids.

Anhydrous sulphuric acid (SO_3) is a white crystalline solid, which unites with the production of much heat with water to form hydrated sulphuric acid (H_2O,SO_3 or H_2SO_4). This is a colourless liquid, of specific gravity about 18·4 as compared with water. It is obtained by the oxidation of sulphurous acid. The operation is conducted in large leaden chambers, into which are introduced —1. Sulphurous acid, formed by burning sulphur or iron pyrites (a compound of sulphur and iron); 2. Steam; 3. Nitric acid; and 4. Atmospheric air. The nitric acid oxidises the sulphurous acid to sulphuric acid, which unites with water from the steam—the nitric acid being reduced to nitric oxide (NO) (p. 321); this immediately takes up oxygen from the air, and forms peroxide of nitrogen (NO_2), which again oxidises more sulphurous acid, and is reduced to nitric oxide. By a constant repetition of this process, a small quantity of nitric acid suffices for the oxidation of a large quantity of sulphurous acid. The sulphuric acid thus formed is concentrated by heat, which drives off much of the water, and leaves an acid nearly corresponding to the formula H_2O,SO_3 or H_2SO_4.

Hydrated sulphuric acid has a great attraction for water, and gives out much heat when mixed with it. It is a powerfully corrosive substance, destroying animal and vegetable tissues, and is sometimes used as a caustic in surgery. It is a very strong acid, driving out most other acids from their salts, and is used for preparing hydrochloric, nitric, acetic, and many other acids. With bases it forms sulphates, such as normal sulphate of potash (K_2O,SO_3 or K_2SO_4); acid sulphate of potash (K_2O,SO_3,H_2O,SO_3 or $KHSO_4$); sulphate of lime (CaO,SO_3 or $CaSO_4$), &c. It is often called oil of vitriol, because it can be obtained by distilling green vitriol or ferrous sulphate (FeO,SO_3 or $FeSO_4$). If the green vitriol be dry, anhydrous sulphuric acid is obtained. A mixture or solution of anhydrous sulphuric acid in hydrated sulphuric acid is known as Nordhausen or fuming sulphuric acid; it is used for dissolving indigo.

Sulphur unites with *hydrogen*, forming sulphuretted hydrogen (H_2S); this is a colourless transparent gas, of specific gravity 1·19. It can be condensed by cold and pressure to a colourless liquid. Water dissolves at ordinary temperatures

about three times its volume of the gas. It has an extremely unpleasant smell, like that of rotten eggs, and acts as a poison upon animals and plants. It is inflammable, burning in air or oxygen with a blue flame, and producing water and sulphurous acid gas. It is most conveniently prepared by the action of dilute sulphuric acid on ferrous sulphide ($FeS + H_2SO_4 = H_2S + FeSO_4$). It acts upon many metallic salts, producing a metallic sulphide and a hydrated acid, thus:

CuO,SO_3 +	H_2S =	H_2O,SO_3 +	CuS.
Sulphate of Copper.	Sulphuretted Hydrogen.	Hydrated Sulphuric Acid.	Cupric Sulphide.

All metallic salts are not thus acted on, and this difference of behaviour is taken advantage of in separating the metals from one another.

Sulphur unites with *carbon* when sulphur-vapour is passed over red-hot charcoal, forming bisulphide of carbon (CS_2), a very volatile liquid, used as a solvent of sulphur, phosphorus, and oils and fats. It is very easily set fire to, and burns with a blue flame, forming carbonic acid and sulphurous acid. As will be seen from its formula, it corresponds to carbonic acid (CO_2); and just as carbonic acid unites with basic *oxides* to form carbonates (such as Na_2O,CO_2), so bisulphide of carbon unites with the *sulphides* of positive metals to form *sulpho*-carbonates (such as Na_2S,CS_2).

PHOSPHORUS is an element very widely diffused in nature. Compounds of phosphorus are essential ingredients in every fertile soil, are absorbed by plants, and pass from plants into animal bodies. The animal tissues containing large quantities of phosphorus are the bones, and the nervous tissues, brain, spinal cord, nerves. Phosphorus can be obtained in two 'allotropic' modifications: 1. Common, yellow, or waxy phosphorus—a translucent yellowish solid of specific gravity 2. It fuses at 112° F. and boils at 550° F. It unites slowly with oxygen at ordinary temperatures, and shines in the dark when exposed to air. It is very easily inflammable, taking fire when moderately warmed in the air, so that it is dangerous to handle it, and it ought to be preserved under water. It is extremely poisonous, and serious and even fatal accidents have occurred from children sucking the ends of lucifer-matches containing phosphorus. 2. Red or amorphous phosphorus is produced from common phosphorus by keeping it for a long time at a temperature slightly below its boiling-point. It is a red solid, and differs very much in character from common phosphorus. It is not fusible; it is not readily inflammable; it is not poisonous. When heated to the boiling-point of common phosphorus, it is changed back into the latter, and therefore takes fire if heated to this temperature in the air.

Compounds of Phosphorus and Oxygen.—Phosphorus combines with oxygen in two proportions, forming, first, anhydrous phosphorous acid (P_2O_3), and second, anhydrous phosphoric acid (P_2O_5). We shall here consider only the latter. When phosphorus is set fire to in air or oxygen, it burns with dazzling brilliancy, forming anhydrous phosphoric acid. This is a snow-white solid, which unites with the greatest readiness with water, giving out much heat. It forms with water three distinct hydrates or hydric salts:

$P_2O_5 + H_2O = H_2O,P_2O_5$ .... Hydric *Meta*phosphate.
$P_2O_5 + 2H_2O = 2H_2O,P_2O_5$ .... Hydric *Pyro*phosphate.
$P_2O_5 + 3H_2O = 3H_2O,P_2O_5$ .... Hydric *Ortho*phosphate.

If in these formulæ we put all the oxygen together, we find that the first and third are divisible by two, so that we have the following formulæ:

Hydric Metaphosphate (or Hydrated Metaphosphoric Acid) .... HPO_3.
Hydric Pyrophosphate (or Hydrated Pyrophosphoric Acid) .... $H_4P_2O_7$.
Hydric Orthophosphate (or Hydrated Orthophosphoric Acid, usually called Common Phosphoric Acid) .. H_3PO_4.

Corresponding to each of these hydrates, there are series of salts; thus, we have metaphosphate of lime (CaO,P_2O_5), metaphosphate of soda (Na_2O,P_2O_5), metaphosphate of silver (Ag_2O,P_2O_5), pyrophosphate of lime ($2CaO,P_2O_5$), pyrophosphate of soda ($2Na_2O,P_2O_5$), pyrophosphate of silver ($2Ag_2O,P_2O_5$), orthophosphate (or common phosphate) of lime ($3CaO,P_2O_5$), common phosphate of soda ($2NaO,H_2O,P_2O_5$), common phosphate of silver ($3Ag_2O,P_2O_5$). It will be observed that in common phosphate of soda we have, as in all common, or ortho, phosphates, three equivalents of base to one P_2O_5, but only two of these are anhydrous soda, the other being water; this salt is, therefore, formally, an acid salt; it has not, however, an acid reaction, and the normal salt, $3NaO,P_2O_5$, is an unstable, highly alkaline body. When an orthophosphate, containing, as in this case, basic water, is heated, water is given off, and a pyrophosphate or metaphosphate is left; thus, when common phosphate of soda is heated, water is given off, and pyrophosphate of soda is left: $2Na_2O,H_2O,P_2O_5 = H_2O + 2Na_2O,P_2O_5$ or $2Na_2HPO_4 = H_2O + Na_4P_2O_7$; and when what is called acid phosphate of soda ($Na_2O,2H_2O,P_2O_5$), which is also an orthophosphate, is heated, water is given off, and metaphosphate of soda is left: $Na_2O,2H_2O,P_2O_5 = 2H_2O + Na_2O,P_2O_5$ or $NaH_2PO_4 = H_2O + NaPO_3$.

Common phosphate of lime ($3CaO,P_2O_5$ or $Ca_3(PO_4)_2$) is the most abundant mineral constituent of bones; and 'bone-ash,' the substance left when bones are burned white in an open fire, so as to destroy all the animal matters, consists chiefly of this phosphate. When treated with sulphuric acid and water, a partial decomposition takes place, which is represented by the following equation: $3CaO,P_2O_5 + 2(H_2O,SO_4) = CaO,2H_2O,P_2O_5 + 2(CaO,SO_4)$. The sulphate of lime ($CaO,SO_4$) being sparingly soluble in water, settles for the most part to the bottom of the vessel in which the decomposition is effected, while the acid phosphate of lime (superphosphate) remains in solution. This superphosphate is largely used as a manure. When superphosphate of lime is heated, it loses water, and leaves metaphosphate of lime: $CaO,2H_2O,P_2O_5 = 2H_2O + CaO,P_2O_5$. From metaphosphate of lime, phosphorus is obtained by heating it in earthenware retorts with charcoal. Two-thirds of the anhydrous phosphoric acid (P_2O_5) are decomposed, the charcoal taking the oxygen to form carbonic oxide, and thus setting the phosphorus free, while one-third remains with all the lime as common phosphate of lime: $3(CaO,P_2O_5) + 10C = 10CO + 4P + 3CaO,P_2O_5$.

Phosphuretted hydrogen, PH_3, is a colourless, transparent gas, having a disagreeable smell. It may be formed by heating phosphorus in a strong solution of caustic potash. As thus formed, it is spontaneously inflammable, taking fire at once on coming into contact with air or oxygen. The

gas owes this spontaneous inflammability to the presence of a small quantity of the vapour of another compound of phosphorus and hydrogen (PH_2).

Phosphorus unites with chlorine and also with bromine in two proportions, corresponding to the two oxides—namely, PCl_3; PCl_5 and PBr_3; PBr_5. The terchloride and terbromide are volatile liquids; the pentachloride and pentabromide are crystalline solids; they all undergo decomposition when brought into contact with water, yielding hydrochloric or hydrobromic acid, and phosphorous or phosphoric acids: $2PCl_3 + 6H_2O = 6HCl + 3H_2O,P_2O_3$; $2PCl_5 + 6H_2O = 6HCl + 3H_2O,P_2O_5$.

FLUORINE is an element the compounds of which resemble to a great extent those of chlorine. It occurs in nature combined with metals, forming salts called fluorides. The most important of these are fluorspar (Derbyshire spar) or fluoride of calcium (CaF_2), and cryolite, which is a compound of fluoride of sodium and fluoride of aluminium ($3NaF,AlF_3$). From these fluorides, hydrofluoric acid (HF) can be obtained by the action of sulphuric acid: $CaF_2 + H_2SO_4 = CaSO_4 + 2HF$. Hydrofluoric acid is a very volatile liquid, dissolving readily in water. It acts very corrosively on animal tissues, and produces severe wounds when applied to the skin. Its most striking chemical character is the way in which it acts upon glass (see Silica), and it is used in the arts for the purpose of etching glass.

SILICON, like carbon, can be obtained in three distinct 'allotropic forms:' two of these are crystalline, corresponding to diamond and graphite; and one is amorphous. Silica, the oxide of silicon (SiO_2), corresponds in formula to carbonic acid, and, like it, is an anhydrous acid, uniting with bases to form silicates. It differs, however, very greatly from carbonic acid in physical characters. It occurs in nature crystallised as rock-crystal or quartz, and obscurely crystallised in flint and chalcedony. Opal is an amorphous form of silica, usually containing some water. Silica fuses at a very high temperature. When heated with bases, it unites with them, forming silicates. Some of these silicates are of great importance. Thus, felspar (one of the ingredients of granite) is a compound of silicate of alumina and silicate of soda, potash, or lime; clay is a silicate of alumina; talc is a silicate of magnesia. Glass is formed of a mixture of silicates; of these, one must be the silicate of potash or silicate of soda: in crown-glass and plate-glass, the other is silicate of lime. In flint-glass, and the glass which is cut into ornaments, silicate of lead is present, sometimes in large proportion. Green bottle-glass owes its colour to silicate of iron.

The silicates of the alkalies (when not combined, as in glass, with other silicates) are soluble in water (water-glass), and are decomposed on the addition of an acid. Thus, sulphuric acid acts on silicate of soda, forming sulphate of soda and hydrated silicic acid, which, under some circumstances, remains dissolved in the water, but readily separates as a jelly. Hydrofluoric acid acts on silica and on the silicates, forming water and gaseous fluoride of silicon (SiF_4). On account of this action, hydrofluoric acid is used for etching glass.

BORON also exists in three forms, corresponding to the three forms of carbon and silicon. Its oxide is anhydrous boracic acid, B_2O_3. Its most important compound is borax, or borate of soda ($Na_2O,2B_2O_3$).

SELENIUM and TELLURIUM are comparatively rare elements, forming compounds nearly corresponding to those of sulphur.

METALS.

The general physical and chemical properties of metals have already been described (p. 312). The characters of the more important metals, and the methods used for extracting them from their ores, are described in the article METALS AND METALLURGY. We shall, therefore, here give only a general sketch of the metals and their compounds. The metals may be divided into several groups, the members of each group having many characters in common. We shall name each group after a metal possessing the common characters in a well-marked degree.

1. The *Sodium* group—comprising Sodium, Potassium, Lithium, Rubidium, and Cæsium.

2. The *Calcium* group—comprising Calcium, Strontium, and Barium.

3. The *Iron* group—comprising Magnesium, Zinc, Cadmium, Iron, Manganese, Chromium, Nickel, Cobalt, Aluminium, and Uranium.

4. The *Copper* group, comprising Copper, Mercury, Lead, and Silver.

5. The *Platinum* group, comprising Gold, Platinum, Palladium, and the rare metals found along with platinum.

6. The *Antimony* group, comprising Arsenic, Antimony, Bismuth, Tin, Titanium, Vanadium, Molybdenum, and Tungsten.

By comparing this list with the table at p. 315, it will be seen that we have not here enumerated all the known metals; those omitted are either too imperfectly known to admit of classification, or too rare to be of practical importance.

1. The oxides of the metals of the *Sodium group* are powerful bases, and unite with water to form soluble hydrates, which cannot be decomposed by heat (Na_2O,H_2O; K_2O,H_2O_3 or $NaHO$; KHO). The bases themselves and their hydrates are called 'alkalies.' The carbonates and phosphates of the alkalies are soluble in water. The metals themselves can be obtained by electrolysis of their fused chlorides, or by the reduction of their carbonates by means of charcoal: $Na_2CO_3 + 2C = 2Na + 3CO$. They decompose water at the ordinary temperature, hydrogen being given off, and the hydrated base remaining in solution: $2Na + 2H_2O = Na_2O,H_2O + H_2$.

The most important salts of this group of metals are: Chloride of sodium (common salt) (see p. 324); sulphate of soda (Glauber's salt) (see p. 324); carbonate of soda (Na_2O,CO_2) (washing-soda). This salt is made from sulphate of soda (which is prepared by acting on common salt with sulphuric acid) by heating it with coal and limestone, dissolving out the carbonate of soda thus formed, by means of water, and evaporating the solution. Bicarbonate of soda, baking-soda (Na_2O,CO_2,H_2O,CO_2 or $NaHCO_3$), is prepared by the action of carbonic acid gas on crystallised carbonate of soda. Nitrate of soda (Chili saltpetre), Na_2O,N_2O_5 or $NaNO_3$, occurs in large quantity in Bolivia, and is used for preparing nitric acid, and also as a manure to supply nitrogen

to growing plants. Phosphate of soda (see p. 326); borate of soda (borax) (see p. 327). Chloride of potassium, or muriate of potash (KCl), is found in the salt mines of Stassfurth, near Magdeburg. Carbonate of potash (K_2O,CO_2) is prepared from the ashes of plants. The plants contain various salts of potash, with acids containing carbon, hydrogen, and oxygen (organic acids). These when burnt are converted into water and carbonic acid, which go off into the air, and carbonate of potash, which remains in the ash. The ash is then treated with water, which dissolves the soluble salts, the solution is evaporated, and the less soluble salts crystallise out (see p. 305), leaving the carbonate of potash in the mother-liquor. This is then evaporated to dryness, and the solid substance remaining forms the 'potashes' of commerce, and consists chiefly of carbonate of potash. Nitrate of potash (K_2O,N_2O_5 or KNO_3). Nitre, or saltpetre (see p. 322), is obtained in Bengal from earth containing it, by treating the earth with water, and evaporating the solution. It is also formed from nitrate of lime by the action of chloride of potassium ($CaO,N_2O_5+2KCl=K_2O,N_2O_5+CaCl_2$). It is used for making gunpowder; see CHEMISTRY APPLIED TO THE ARTS.

Lithium, rubidium, and cæsium are comparatively rare metals, generally resembling sodium and potassium.

2. *Calcium group* (or metals of the alkaline earths). The oxides of these metals—Lime (CaO); Strontia (SrO); and Baryta (BaO)—are powerful bases, and unite with water to form hydrates soluble in water. Thus, lime, when treated with water, unites with it, giving out a great deal of heat, and forming 'slaked lime.' The solution of slaked lime in water is called 'lime-water.' The *normal* carbonates and phosphates of this group are insoluble in water. If a current of carbonic acid is passed into lime-water, a white precipitate of carbonate of lime is formed (CaO,CO_2 or $CaCO_3$). This action enables us to test for carbonic acid in air; thus, if a jar of air is shaken up with a definite quantity of lime-water, the proportion of carbonic acid present can be approximately estimated by the degree of milkiness produced. If the current of carbonic acid is continued after all the lime has been converted into carbonate, the milkiness gradually disappears, as carbonate of lime is soluble in water containing carbonic acid, probably on account of the formation of a bicarbonate of lime (CaO,CO_2,H_2O,CO_2). We cannot obtain this bicarbonate in the solid state, because, when the solution is evaporated or boiled, carbonic acid escapes, and carbonate of lime is precipitated. This solubility of carbonate of lime in water containing carbonic acid is of great practical importance. Water filtering through the soil takes up carbonic acid from decaying vegetable matters, and if it then comes in contact with carbonate of lime (limestone, or chalk), it dissolves it. Water thus charged with bicarbonate of lime, deposits carbonate of lime whenever it is exposed to the air: thus, if such water drops from the roof of a cave or from an overhanging rock, each drop before it falls loses some carbonic acid, and deposits some carbonate of lime on the rock: this deposit, increased by every drop which runs over it, gradually forms a dependent mass of carbonate of lime, hanging down from the rock; such a mass is called a 'stalactite.' But the drops do not lose *all* their carbonic acid before falling, and therefore do not deposit *all* their carbonate of lime on the stalactite, so that if they fall upon a rock or upon the floor of the cave, they there, evaporating still more, deposit a further quantity of carbonate of lime; and this second deposit forms a mass, gradually increasing in height, which is called a 'stalagmite.' As the stalactite grows down, and the stalagmite grows up, they sometimes meet, and form a continuous column, which grows in thickness from the deposits formed by the water, which now runs down the surface of the column.

When carbonate of lime is heated, it decomposes into lime and carbonic acid. This is the change effected in the lime-kiln. The lime (CaO) thus obtained is called 'quicklime,' to distinguish it from the hydrate or slaked lime. Common mortar consists of sand, slaked lime, and water. The sand acts merely mechanically to prevent the mortar shrinking; the hardening of the mortar depends on the slow conversion of the hydrate of lime into carbonate by the action of the carbonic acid of the air ($CaO,H_2O+CO_2=CaO,CO_2+H_2O$). Hydraulic mortar, or cement, consists of slaked lime, sand, burnt clay, and water. Here the sand acts also merely mechanically; but the burnt clay (which is frequently introduced by using a limestone containing clay, so that the two are burnt together) contains silica (SiO_2) in a condition such that it can slowly unite with the lime, and form silicate of lime (CaO,SiO_2), and it is upon this union that the hardening or setting of hydraulic mortar or cement depends. Other important salts of lime are: The phosphate (see p. 326); the nitrate (see p. 322). The sulphate ($CaOSO_3$ or $CaSO_4$) occurs *anhydrous* in the mineral anhydrite, also with two molecules of water of halhydration (see p. 316) as selenite or gypsum. When gypsum is heated to about 500° C. it loses all its water, and is converted into 'plaster of Paris.' The setting of plaster of Paris, when mixed with water, depends on the sulphate of lime taking up the water to form again the halhydrated salt ($CaO,SO_3,2H_2O$). Sulphate of lime is very sparingly soluble in water. Water containing lime salts in solution is 'hard;' that is, it requires a greater quantity of soap to form a lather than soft water does (see CHEMISTRY APPLIED TO THE ARTS). The chief lime salts occurring in hard water are the carbonate and the sulphate. The former can be almost entirely removed by boiling, hence the hardness caused by its presence is called removable hardness; that caused by the sulphate is called permanent hardness. The crust which forms in kettles and boilers in which hard water is boiled, consists usually of both carbonate and sulphate of lime.

The compounds of barium and strontium resemble generally those of calcium. Baryta and strontia are more soluble than lime; their sulphates are nearly insoluble in water. The metals barium, strontium, and calcium can be obtained by the electrolysis of their fused chlorides.

3. *Metals of the Iron group.*—Iron forms two basic oxides—namely, protoxide of iron or ferrous oxide (FeO), and sesquioxide, or peroxide, or ferric oxide (Fe_2O_3); each of these forms salts with acids, and these two series of salts are quite different in character from each other. Some metals of the group, like iron, form two basic

oxides (manganese, MnO and Mn_2O_3; chromium, CrO and Cr_2O_3; and Uranium, UO and U_2O_3); some have only the oxide corresponding to ferrous oxide (magnesium, MgO; zinc, ZnO; cadmium, CdO); while aluminium has only the oxide corresponding to ferric oxide, Al_2O_3. Nickel and cobalt form both oxides, NiO and Ni_2O_3,CoO and Co_2O_3; but the peroxide of cobalt has scarcely any basic character, and the peroxide of nickel has none.

Magnesium occurs in nature in the carbonate of magnesia (MgO,CO_2), the mineral magnesite, and associated with carbonate of lime in magnesian limestone, or dolomite; in the sulphate of magnesia (Epsom salts, $MgO,SO_3,7H_2O$), which is found in many mineral waters. Chloride and bromide of magnesium occur in small quantities in sea-water. Steatite and meerschaum are silicates of magnesia. The soluble salts of magnesia have a peculiar bitter taste. The metal magnesium can be obtained by the electrolysis of fused chloride of magnesium, or by the action of sodium on chloride of magnesium ($MgCl_2 + 2Na = 2NaCl + Mg$). It is a bright white metal, of specific gravity 1·75; when heated to redness in air or oxygen, it takes fire, burning with an intensely bright white light, and producing magnesia.

Zinc occurs in nature as zincblende (sulphide of zinc, ZnS), carbonate of zinc (ZnO,CO_2), and silicate of zinc. The method of obtaining it from its ores is described in the article METALS AND METALLURGY. Its oxide (ZnO) is formed when the metal is strongly heated in air or oxygen. Sulphate of zinc (white vitriol) is formed when the oxide is dissolved in sulphuric acid, or when sulphuric acid (hydric sulphate) or cupric sulphate acts on metallic zinc: $Zn + H_2SO_4 = H_2 + ZnSO_4$ or $Zn + CuSO_4 = Cu + ZnSO_4$. It crystallises (like Epsom salts) with seven molecules of water, of which one is water of halhydration, and can be driven off only at a high temperature. Chloride of zinc, $ZnCl_2$, formed by dissolving oxide of zinc or metallic zinc in hydrochloric acid ($ZnO + 2HCl = H_2O + ZnCl_2$ or $Zn + 2HCl = H_2 + ZnCl_2$), is a very soluble salt; it is used in surgery as a caustic, and a strong solution of it is sold under the name 'Burnett's Disinfecting Solution.'

Cadmium usually occurs in nature along with zinc, which it greatly resembles. The sulphide of cadmium (CdS) is yellow, and is used as a pigment.

Iron occurs in nature free as native iron, probably always in the form of meteoric masses which have fallen upon the earth. We know nothing of the origin of these meteoric stones; they appear to have been bodies moving through space, which, coming into the earth's atmosphere, have been attracted to the earth, and so have fallen upon its surface. Iron occurs in combination with oxygen as ferric oxide (red hæmatite, specular iron ore, Fe_2O_3); as hydrated ferric oxide (limonite, goethite, brown hæmatite); as magnetic iron ore, or ferroso-ferric oxide (FeO,F_2O_3). Ferrous carbonate (FeO,CO_2) occurs pure in spathic iron ore, mixed with clay in the clay iron ore, and mixed with coal in the black-band iron-stone; ferrous silicate occurs in many minerals. The most abundant compound of iron and sulphur is iron pyrites (FeS_2). The most important compounds of iron (not treated of in the paper on METALS AND METALLURGY) are: 1. The Ferrous Compounds: Ferrous Sulphide (FeS), formed by the direct union of iron and sulphur heated together, a black, fusible substance, used as a source of sulphuretted hydrogen, which is easily obtained from it by treating it with dilute acids, thus: $FeS + H_2SO_4 = H_2S + FeSO_4$. Ferrous Carbonate; see above. Ferrous Sulphate (green vitriol), formed by the action of dilute sulphuric acid on iron or on ferrous sulphide ($Fe + H_2SO_4 + H_2 + FeSO_4$ or $FeS + H_2SO_4 = H_2S + FeSO_4$), also by the oxidation of iron pyrites in the presence of water ($FeS_2 + H_2O + 7O = FeSO_4 + H_2SO_4$), also by the action of cupric sulphate on metallic iron ($Fe + CuSO_4 = Cu + FeSO_4$); green vitriol crystallises (like Epsom salts and white vitriol) with seven molecules of water, six of which are water of crystallisation, and one water of halhydration. 2. Ferric Compounds: Ferric Oxide (Fe_2O_3) occurs in nature as red hæmatite. Ferric Chloride ($FeCl_3$) is formed by dissolving ferric oxide in hydrochloric acid ($Fe_2O_3 + 6HCl = 3H_2O + 2FeCl_3$), or by oxidising ferrous chloride in the presence of hydrochloric acid ($2FeCl_2 + 2HCl + O = 2FeCl_3 + H_2O$). Ferric chloride is the substance often called muriate of iron, and is used in medicine—a solution of it in weak alcohol is sold as 'steel drops.' The 'rust' of iron is a ferric compound, being a hydrate of ferric oxide, and having nearly the same composition as the mineral *limonite*. Ferric oxide is a comparatively weak base, and (see p. 308) acts also as a weak (anhydrous) acid. So we have compounds of ferric oxide with stronger bases—as with magnesia in magnesic ferrite (MgO,Fe_2O_3); with ferrous oxide in magnetic iron ore (FeO,Fe_2O_3); with oxide of zinc in franklinite, &c. 3. We have a series of salts (of which only a few are known), the Ferrates, as ferrate of potash (K_2O,FeO_3), in which iron appears to play the part of sulphur—K_2O,FeO_3 corresponding to sulphate of potash, K_2O,SO_3.

Manganese.—The most important compounds of manganese are: 1. Peroxide of Manganese MnO_2), which has been already mentioned (p. 324) as used in making chlorine. 2. The Manganous Salts, corresponding to the ferrous salts, as MnO,SO_3; $MnCl_2$; &c. 3. Manganic Salts, which easily lose oxygen, and are transformed into manganous salts (as $Mn_2O_3,3SO_3 + H_2O = 2(MnO,SO_3) + H_2O,SO_3 + O$).

Chromium occurs in nature chiefly as chrome iron ore (FeO,Cr_2O_3), a compound in which chromic oxide (Cr_2O_3) acts as an acid. Its most important compounds are the *chromates*, corresponding to the ferrates or sulphates, as chromate of potash (K_2O,CrO_3), bichromate of potash ($K_2O,2CrO_3$). Chrome yellow is chromate of lead (PbO,CrO_3). Chromic acid, a red crystalline substance (CrO_3), is a powerful oxidising agent, easily giving up half of its oxygen to form chromic oxide (Cr_2O_3).

Nickel and *Cobalt* have already been referred to as forming compounds perfectly analogous to the ferrous salts. Silicate of cobalt is remarkable for its intense blue colour; in the state of fine powder it forms the pigment 'smalt.'

Aluminium.—The most important compounds of this metal are its oxide alumina (Al_2O_3) and the salts of this oxide. Alumina occurs in nature pure as 'corundum;' coloured by small quantities of other oxides, as sapphire, topaz, ruby, and

amethyst. Emery is corundum mixed with ferric oxide. Combined with water, it forms the minerals diaspore and gibbsite. Clay is a silicate of alumina, and is formed in nature by the decomposition of felspar. There are three chief species of felspar—potash felspar, soda felspar, and lime felspar—silicates respectively of alumina and potash, alumina and soda, and alumina and lime. Sulphate of alumina (concentrated alum) is formed by the action of sulphuric acid on clay. Common alum is a double sulphate of alumina and potash ($K_2O,SO_3,Al_2O_3,3SO_3,24H_2O$).

Uranium occurs in the mineral pitchblende, which is essentially an oxide corresponding to magnetic oxide of iron (UO,U_2O_3). This oxide is used for producing an intense and permanent black colour on porcelain. Uranic oxide (U_2O_3) forms a silicate of a yellowish green colour, and is used to give this colour to glass.

4. *Copper Group.*—Copper forms two basic oxides—cuprous oxide, red oxide of copper (Cu_2O), and cupric oxide, black oxide of copper (CuO). There are two corresponding oxides of mercury (Hg_2O and HgO), but silver forms only one *basic* oxide (Ag_2O), peroxide of silver (AgO) not being a base. The only *basic* oxide of lead is that corresponding to cupric oxide—namely, plumbic oxide (PbO).* Copper occurs free, as 'native copper,' in large quantities in North America, particularly in the neighbourhood of Lake Superior; in combination with oxygen, as cuprous oxide (red copper ore), in Siberia, in Cornwall, and in Australia; as cupric oxide (CuO), near Lake Superior; as carbonate (malachite, lazurite); combined with sulphur as 'gray sulphide of copper' (Cu_2S) in Cornwall; along with sulphide of iron as copper pyrites ($CuFeS_2$), the most abundant of all the copper ores, in Cornwall, Devonshire, Sweden, and many parts of the United States; along with sulphide of antimony and sulphide of arsenic as sulphantimonite and sulpharsenite of copper, in the so-called 'fahl ore.'

The most important salts of copper are the cupric salts: Cupric sulphate (CuO, SO_3 or $CuSO_4$), formed by the oxidation of sulphide of copper, or by the action of strong sulphuric acid at a high temperature on metallic copper ($Cu + 2H_2SO_4 = CuSO_4 + 2H_2O + SO_2$). It crystallises as blue vitriol or blue stone with five molecules of water, one of which is water of halhydration (p. 316). Cupric nitrate (CuO,N_2O_5 or $Cu(NO_3)_2$), formed by the action of nitric acid on metallic copper (p. 321), or on cupric oxide ($3Cu+4(H_2O,N_2O_5)= 3(CuO,N_2O_5)+2NO+4H_2O$; $CuO+H_2O,N_2O_5= H_2O + CuO,N_2O_5$), is a blue salt, which, when heated, gives cupric oxide, peroxide of nitrogen, and oxygen ($CuO,N_2O_5 = CuO + 2NO_2 + O$).

Mercury occurs in nature free as native mercury, but much more frequently as cinnabar, the mercuric sulphide (HgS). The most important compounds of mercury are: Mercuric sulphate (HgO,SO_3), formed by the action of strong sulphuric acid at a high temperature on metallic mercury ($Hg + 2H_2SO_4 = HgSO_4+2H_2O+SO_2$); mercuric chloride (corrosive sublimate, $HgCl_2$), formed by heating common salt with mercuric sulphate ($HgO,SO_3+2NaCl=Na_2O,SO_3+HgCl_2$); the corrosive sublimate being volatile, rises in vapour, and is condensed in the cold parts of the apparatus. It is soluble in water, and very poisonous. The mercurous salts are formed by adding metallic mercury to the mercuric salts; thus, calomel (mercurous chloride, $HgCl$) may be formed by heating 271 parts of corrosive sublimate with 200 of mercury ($HgCl_2+Hg=2HgCl$), or by heating mercuric sulphate with metallic mercury and common salt ($HgSO_4+Hg+2NaCl= Na_2SO_4 + 2HgCl$); the calomel is volatile, and sublimes, collecting on the cold parts of the apparatus. It is insoluble in water, and can, therefore, be freed from any corrosive sublimate which may be mixed with it by washing with water. Vermilion is mercuric sulphide.

Lead occurs chiefly as galena (plumbic sulphide, PbS). It forms three oxides: 1. Plumbic oxide (litharge, massicot, PbO). This is produced when lead is strongly heated in air or oxygen. When fused, it forms brown scales (litharge); when prepared at a lower temperature, so that it is not fused, it is a yellow powder (massicot). It is the only basic oxide of lead. 2. Red lead. This oxide is formed when litharge is exposed at a temperature considerably below its fusing-point to the action of air or oxygen; its composition is somewhat variable, but corresponds pretty closely to the formula Pb_3O_4. It may be regarded as a compound of plumbic oxide and the third oxide of lead, peroxide of lead. When treated with nitric acid, it forms plumbic nitrate and peroxide of lead ($2PbO,PbO_2 + 2(H_2O,N_2O_5) = 2(PbO,N_2O_5) + 2H_2O + PbO_2$). White-lead is a compound of carbonate of lead and hydrated oxide of lead. It is formed by exposing metallic lead to air, carbonic acid, water-vapour, and the vapour of vinegar. Sulphate of lead (PbO,SO_3) is insoluble in water; for this reason, persons working in lead are recommended to add a small quantity of sulphuric acid to the water they drink, as the insoluble sulphate is not poisonous. Sulphide of lead is black, and all pigments containing lead are blackened by sulphuretted hydrogen, on account of the formation of the sulphide. Chrome yellow is chromate of lead (PbO,CrO_3).

Silver occurs in nature free as native silver, as chloride in 'horn silver,' as sulphide (Ag_2S) both alone and mixed with other sulphides, most specimens of galena (sulphide of lead) containing some silver, also in fahl ore as sulphantimonite of silver. The most important compounds of silver are: Nitrate of silver (Ag_2O,N_2O_5), formed by the action of nitric acid on silver ($6Ag + 4H_2O,N_2O_5 = 3(Ag_2O,N_2O_5) + 2NO + 4H_2O$). It is soluble in water, and is used in photography, and as a mild caustic (lunar caustic) in surgery. Chloride of silver ($AgCl$) is insoluble in water and acids, soluble in ammonia. British 'standard silver,' of which our silver coins are made, is an alloy of silver and copper, containing in 100 parts, 92·5 of silver and 7·5 of copper. It is harder than pure silver.

5. Of the Platinum group, we need only mention gold and platinum. These metals occur chiefly free, as native gold and native platinum. They are not dissolved by either nitric or hydrochloric acid, but are converted into chlorides ($AuCl_3$ and $PtCl_4$) by the action of chlorine, or of a mixture of nitric and hydrochloric acids (aqua regia). These chlorides unite with the chlorides of the metals of the alkalies, forming double salts, as,

* It is with some hesitation that we place lead in this group; the characters of the lead salts would incline us to group it with calcium, strontium, and barium.

aurochloride of potassium ($KCl,AuCl_3$), aurochloride of sodium ($NaCl,AuCl_3$), platinochloride of potassium ($2KCl,PtCl_4$), platinochloride of sodium ($2NaCl,PtCl_4$). Platinochloride of potassium is sparingly soluble in water, insoluble in a mixture of alcohol and ether; very similar to it is the platinochloride of ammonium ($2NH_4Cl,PtCl_4$). When the latter salt is heated, chloride of ammonium, hydrochloric acid, and nitrogen are given off, and metallic platinum is left as a spongy, porous mass (spongy platinum). British standard gold is an alloy of gold and copper, containing in 12 parts, 11 of gold and 1 of copper.

6. The metals of the Antimony group resemble, in many respects, the non-metallic elements; arsenic, antimony, and bismuth being analogues of phosphorus; while tin has many points of resemblance to silicon. Vanadium, molybdenum, and tungsten are comparatively rare metals.

Arsenic occurs in nature combined with sulphur in realgar (AsS) and orpiment (As_2S_3); with metals, particularly iron, in mispickel and arsenical pyrites (almost all specimens of iron pyrites contain some arsenic, which thus occurs in sulphuric acid prepared from pyrites (see CHEMISTRY APPLIED TO THE ARTS. When arsenical ores are heated in a current of air, the arsenic is converted into 'white arsenic,' or arsenious acid (As_2O_3). Arsenious acid, when heated with nitric acid, is oxidised to form arsenic acid ($3H_2O,As_2O_5$), an acid very closely resembling phosphoric acid ($3H_2O,P_2O_5$). Arsenious and arsenic acids form arsenites and arseniates with bases. Arsenite of copper is the green pigment known as 'Scheele's green.' 'Schweinfurt green' is a compound of arsenite of copper and acetate of copper. All these compounds of arsenic are highly poisonous.

Antimony occurs in nature chiefly as sulphide of antimony (Sb_2S_3). Its most important compounds are: Antimonious oxide (Sb_2O_3), a weak base, forming salts with some acids. Tartar emetic is the double tartrate (see p. 335) of potash and antimony ($K_2O,Sb_2O_3,\bar{T}$, where $\bar{T}$ stands for anhydrous tartaric acid). Chloride of antimony ($SbCl_3$) is formed by the action of strong hydrochloric acid on sulphide of antimony; when poured into water, it forms a white precipitate, 'powder of algaroth,' or oxychloride of antimony ($3SbCl_3 + 3H_2O = 6HCl + Sb_2O_3,SbCl_3$ or $SbCl_3 + H_2O = 2HCl + SbOCl$).

Tin occurs in nature as 'tinstone' or stannic oxide (SnO_2), corresponding to silica (SiO_2). The most important compounds of tin are: Stannous chloride, 'salt of tin,' or 'pink salt' ($SnCl_2$), formed by the action of hydrochloric acid on tin ($Sn + 2HCl = H_2 + SnCl_2$). It is soluble in water, and is used as a mordant in dyeing (see CHEMISTRY APPLIED TO THE ARTS). Stannic chloride ($SnCl_4$), formed by the addition of chlorine to stannous chloride. It is a colourless, volatile liquid. Stannic oxide acts as an anhydrous acid, and forms salts called stannates.

Compounds of the metals with one another are called *alloys*. They resemble metals in their physical characters. We shall mention a few of the most important.

Brass, 64 parts copper and 36 parts zinc; German silver, 51 parts copper, 30·5 parts zinc, and 18·5 parts nickel; bell-metal, 78 parts copper and 22 parts tin; bronze, 80 parts copper, 4 parts zinc, and 16 parts tin; coinage bronze, 95 parts copper, 1 part zinc, and 4 parts tin; aluminium bronze, 90 parts copper and 10 parts aluminium; solder, from 2 parts tin and 1 part lead, to 1 part tin and 2 parts lead; pewter, 4 parts tin and 1 part lead; Britannia metal, pewter with a little copper and antimony; type-metal, 2 parts lead, 1 part tin, and 1 part antimony; standard (or 22 carat) gold contains in 24 parts, 22 of gold and 2 of copper. Alloys containing less gold are used in jewellery—such as 18-carat gold, containing 18 parts gold in 24; 16-carat gold, containing $\frac{16}{24}$ of pure gold; &c.

Standard silver, as already stated, contains 7·5 per cent. of copper.

The alloys of mercury are called amalgams. Tin amalgam is used for silvering looking-glasses. For details respecting the metals, the reader is referred to the article on METALS AND METALLURGY.

ORGANIC CHEMISTRY.

The term 'Organic Chemistry' was first employed to express that department of chemistry which treats of the substances peculiar to animals and vegetables, and the direct derivatives of these substances. As almost all these substances contain carbon, and as almost all compounds of carbon are practically obtained from animal or vegetable products, it is now found more convenient to group all carbon compounds together, and to define organic chemistry as the chemistry of the compounds of carbon. These compounds are so numerous, and many of them so complex, that it is impossible in a sketch like this to do more than shortly describe the relations of a few of them, selected on account of their practical importance.

Some of the simpler carbon compounds—carbonic acid, carbonic oxide, marsh gas, and olefiant gas—have already been described (p. 323), and are therefore omitted here. We shall begin with a large and very important group of compounds known as the 'carbohydrates.' This name implies, not that they contain carbon and water, but that they contain carbon, hydrogen, and oxygen, and that the hydrogen and oxygen are present in them in the same proportion as in water. The most important members of the group are: 1. The sugars; 2. Starch, gum, and inulin; and 3. Cellulose.

1. Sugars are substances, soluble in water, having a sweet taste, and capable of undergoing the peculiar chemical change called the vinous fermentation, which will be described farther on (p. 332). They may be divided into two sets: 1. Those analogous to grape-sugar; and 2. Those analogous to cane-sugar. Honey and the juice of sweet fruits contain principally grape-sugar. These can also be prepared from cane-sugar and its analogues, and from starch, inulin, or cellulose. The formula of grape-sugar is $C_6H_{12}O_6$. Cane-sugar and milk-sugar are the most important sugars of the second set. Cane-sugar is obtained from the juice of the sugar-cane, from the juice of the beetroot, from the sugar-maple, and from the sugar-palms. It occurs mixed with sugars of the first set in most sweet fruits. Milk-sugar is contained in the milk of all mammals, and is obtained by evaporating the whey, and allowing the sugar

to crystallise out. The formula of cane-sugar and milk-sugar is $C_{12}H_{22}O_{11}$. When cane-sugar is boiled with dilute acids, or mixed with water and 'diastase' (a peculiar substance contained in malt), it takes up water, and is converted into *dextrose* and *levulose*, two sugars of the first, or grape-sugar, set: $C_{12}H_{22}O_{11}+H_2O=C_6H_{12}O_6+C_6H_{12}O_6$. Milk-sugar undergoes a similar change.

The two sets of sugar are chiefly distinguished from one another by the readiness with which they undergo chemical change, the second set being the more stable. Thus, in fermentation, cane and milk sugars are first changed into sugars of the grape-sugar set, and then these ferment. Cane-sugar can be obtained in crystals, as in loaf-sugar and sugar-candy; when heated, it fuses, and on cooling, forms a clear, glassy, non-crystalline mass, 'barley-sugar,' which, if long kept, goes back into the crystalline form. More strongly heated, it loses water, and is converted into a dark-brown substance, called caramel, which is largely used for colouring rum and brandy.

2. Starch occurs in many parts of plants, as in the seeds of cereal grains, in the tubers of the potato, in the stems of the sago-palm, &c. When starch is examined under the microscope, it is seen to consist of small rounded granules; these granules vary considerably in size and shape in different plants, so that it is possible, by means of the microscope, to discover the source from which a specimen of starch was derived. Starch is insoluble in cold water; when treated with hot water, the granules swell up, and form a paste, which, when diluted, has all the appearance of a solution. Starch-paste is coloured blue by iodine, and may thus be used as a test for free iodine; similarly, iodine is used as a test for starch. When starch is heated alone, or with a small quantity of acid, it is converted into *dextrine*, a soluble gummy substance, much used in the arts under the name of British gum. Prolonged boiling with dilute acids, and also contact with some animal liquids, convert starch into *dextrose*, a sugar of the grape-sugar set. The same change takes place in the starch contained in seeds during the process of germination. Thus, malt, which is grain in which the process of germination has been arrested, contains, not starch, but dextrine and dextrose derived from starch. Malt also contains a remarkable substance called 'diastase,' which converts starch into dextrine and dextrose.

Inulin resembles starch very much; it occurs in the Jerusalem artichoke, the roots of the dahlia, chicory, &c. It dissolves in hot water, and does not form a jelly like starch. By boiling with dilute acids it is converted into *levulose*, a sugar of the grape-sugar set. Starch, inulin, and dextrine have all the same composition ($C_6H_{10}O_5$).

Gum-arabic is a compound of a base or bases, generally lime, magnesia, and potash, with Arabic acid ($C_6H_{10}O_5$). Gum-senegal, cherry-tree gum, gum-tragacanth, all of which are exudations from trees, have a similar composition.

3. The last carbohydrate of which we shall treat is cellulose. This substance has the same composition as starch, inulin, dextrine, and Arabic acid—namely, $C_6H_{10}O_5$. It occurs in all plants, nearly pure in cotton, wool, and young fibrous cells, such as flax, hemp, &c.; and more or less mixed with resinous and other matters in wood. It is quite insoluble in water. When treated with strong sulphuric acid, it is converted into a jelly, which dries up to a horny mass. If unsized paper, which is almost pure cellulose, is dipped for a few minutes in sulphuric acid diluted with about half its volume of water, then washed and dried, a substance called 'vegetable parchment' is formed, which consists of the fibres of the paper matted together by means of the above-mentioned horny substance. If the jelly is boiled with dilute acid, it is slowly converted into a sugar of the grape-sugar set. Strong nitric acid converts cellulose into gun-cotton. There are several kinds of gun-cotton, the most explosive having the composition $C_6H_7(NO_2)_3O_5$.

FERMENTATION.

If a solution of sugar containing nitrogenous matter is exposed to the air at temperatures between 75° and 95° F. what is called fermentation takes place. There are several kinds of fermentation to which sugar is liable: we shall here consider only two—namely, the vinous or alcoholic, and the lactic. Each kind of fermentation is produced by the growth in the liquid of a special kind of mould or small fungus, which is called a 'ferment;' and fermentation can be prevented by anything which prevents the growth of the fungus: for instance, by keeping away from the liquid the spores or germs from which the fungus springs; by the liquid being either too hot or too cold; by its containing too much sugar; or by the presence of substances which act as poisons to the ferment, and are hence called 'antiseptics.' The fungus or ferment which produces the alcoholic fermentation is called 'yeast;' that which produces the lactic fermentation is probably the mould called *Penicillium glaucum*, the common 'blue mould.' The vinous fermentation proceeds most favourably between 75° and 85° F.; the lactic, between 85° and 95°. In the vinous fermentation, the sugar is changed into alcohol and carbonic acid gas, the latter escaping in bubbles from the surface, and giving rise to an appearance of frothing, whence the name 'fermentation.' Some other substances, 'secondary products of fermentation,' are produced at the same time in small quantity. The chief chemical change may be represented by the equation,

$$\underset{\text{Glucose.}}{C_6H_{12}O_6} = \underset{\text{Alcohol.}}{2C_2H_6O} + \underset{\text{Carbonic Acid.}}{2CO_2}.$$

In the lactic fermentation, the sugar is changed into lactic acid—thus:

$$\underset{\text{Glucose.}}{C_6H_{12}O_6} = \underset{\text{Lactic Acid.}}{2C_3H_6O_3}.$$

The alcoholic fermentation occurs in the making of bread. See CHEMISTRY APPLIED TO THE ARTS. Alcohol is obtained from fermented liquors by distillation (see p. 306). Pure alcohol is a colourless liquid, of specific gravity 0·794, boiling at 173° F. Its composition is indicated by the formula C_2H_6O. It is inflammable, burning with a feebly luminous flame, and producing carbonic acid and water. It is capable of dissolving many substances, and is used as a solvent for resins: an alcoholic solution of shellac is the common 'spirit varnish.'

Alcohol acts upon acids in a manner very similar to that of bases. Thus, with hydrochloric acid,

alcohol yields water and a volatile substance called hydrochloric ether, or chloride of ethyl; just as caustic soda, with hydrochloric acid, yields water and chloride of sodium, $C_2H_6O + HCl = H_2O + C_2H_5Cl$, corresponding to $NaHO + HCl = H_2O + NaCl$; and as caustic soda is regarded as the oxide of hydrogen and sodium, and represented by the graphic formula, Na—O—H, so we may call alcohol the oxide of hydrogen and ethyl, C_2H_5—O—H. The substances produced by the action of acids upon alcohol (which may be looked upon as the *salts* of ethyl) are called 'compound ethers' or 'esters,' and are named after the acid employed in producing them: thus, nitrous acid acts on alcohol to produce nitrous ether; acetic acid, to produce acetic ether; and so on. The analogy between the compounds of ethyl and those of such a metal as sodium can be carried farther; and just as we have anhydrous oxide of sodium, Na_2O or Na—O—Na, so we have anhydrous oxide of ethyl, $(C_2H_5)_2O$ or C_2H_5—O—C_2H_5. This substance is common ether, often, but improperly, called sulphuric ether, because sulphuric acid is used in making it. When alcohol is mixed with sulphuric acid, the first change which takes place is the formation of water and 'sulphovinic acid,' which is the acid sulphate of ethyl, $C_2H_5OH + H_2SO_4 = HOH + C_2H_5HSO_4$. This sulphovinic acid is obviously the analogue of bisulphate of soda, $NaHSO_4$. When sulphovinic acid is heated along with alcohol, ether and sulphuric acid are formed—thus, $C_2H_5OH + C_2H_5HSO_4 = C_2H_5{-}O{-}C_2H_5 + H_2SO_4$. In the ordinary process for making ether, these two actions go on together, so that the sulphovinic acid is decomposed as fast as it is formed, and ether and water distil over together, leaving sulphuric acid behind. A comparatively small quantity of sulphuric acid is thus able to convert a large quantity of alcohol into ether and water.

Common ether is a colourless liquid, of specific gravity 0·723, boiling at 96° F. It is therefore a very volatile substance; and as it evaporates rapidly below its boiling-point, it can be used to produce intense cold. It is also used as a solvent for fats and oils, and as an anæsthetic in surgery.

Acetous Fermentation, Acetic Acid.—If fermented liquors—that is, solutions containing alcohol and nitrogenous substances—are exposed to the air, they gradually become sour, and what is called 'vinegar' is produced. This change is known as the 'acetous fermentation,' and, like other fermentations, depends on the growth of a fungus, *Mycoderma aceti*, the vinegar-plant, or 'mother of vinegar.' The acetous fermentation not only requires the presence and growth of a ferment, but also the presence of air or oxygen, and in this differs essentially from the other two kinds of fermentation which we have been considering. It is, in fact, a process of oxidation taking place under the influence of the ferment. In the 'quick process' for making vinegar, weak alcohol is made to trickle through casks containing wood-shavings, and pierced with holes for the admission of air. The shavings become coated with *mycoderma*, and the oxidation of the alcohol proceeds very rapidly. Alcohol can also be oxidised by various oxidising agents, and we can thus trace the process more minutely than is possible in the case of the acetous fermentation. When alcohol is heated with a mixture of sulphuric acid and solution of bichromate of potash (or what comes to the same thing, sulphuric acid and chromic acid), the alcohol loses hydrogen, and the chromic acid loses oxygen; these combine to form water, and the chromic acid is reduced to chromic oxide, which, with the sulphuric acid, forms chromic sulphate. The alcohol, by the loss of hydrogen, is converted into a very volatile liquid, called aldehyd (*al*cohol *dehyd*rogenatum—that is, alcohol from which hydrogen has been removed), having the composition indicated by the formula C_2H_4O—that is, $C_2H_6O - H_2$. Aldehyd is very easily oxidised, readily taking up another atom of oxygen, and forming acetic acid, $C_2H_4O_2$. Besides the oxidation of alcohol, there are various ways in which acetic acid can be produced; of these, the most practically important is the distillation of wood. As has been already stated (p. 332), wood consists principally of cellulose. When it is heated to redness in a retort, closed so as to exclude air, and provided with a tube, by which the gaseous and volatile products can be led to a cooling and condensing apparatus, a great many different substances are formed. They may be grouped thus: 1. The charcoal which remains in the retort; 2. Uncondensable gases which pass through the condenser; and 3. Volatile substances, which flow as liquids from the condenser. Of these we may again distinguish the *tar*, which contains the substances insoluble, or sparingly soluble in water, and a watery liquid floating upon the tar, and consisting chiefly of water, acetic acid, and a light inflammable liquid called pyroxylic spirit. These may be separated from one another by converting the acetic acid into an acetate by the addition of a base (soda, lime, or oxide of lead) distilling off the pyroxylic spirit; and, if the acetic acid is required as such, decomposing the acetate by means of sulphuric acid, and distilling. Pure acetic acid is a colourless liquid, with a pure sour taste and pungent odour; at 32° F. it freezes, and forms a colourless crystalline mass, which does not fuse till the temperature is raised to about 60° F. The specific gravity of the liquid is 1·063. It boils at 246° F. Its composition is represented by the formula $C_2H_4O_2$. The strongest vinegar of commerce contains about 5 per cent. of pure acetic acid. The most important acetates are: Acetate of soda, acetate of lead (sugar of lead), basic acetate of lead (Goulard's solution), acetate of copper, basic acetate of copper (verdigris), acetate of alumina, and ferric acetate; the last two are used as mordants in dyeing and calico-printing.

ALCOHOLS AND THEIR DERIVATIVES.

Many substances have a chemical character similar to that of common alcohol—that is to say, they form compound ethers when treated with acids, lose two atoms of hydrogen to form bodies analogous to aldehyd, which, again, easily take up oxygen, and are converted into acids corresponding to acetic acid. Thus, there is a substance contained in pyroxylic spirit called 'methylic alcohol,' which has the formula CH_4O (or CH_3—O—H). With hydrochloric acid, it forms water and CH_3Cl, chloride of methyl; when oxidised, it is converted into CH_2O, its aldehyd; and this, again, into CH_2O_2, formic acid. Formic acid is interesting as the acid contained in the bodies of red ants, and in the stinging fluid of the common

nettle. To take another example, common fousel oil (see p. 306) consists mainly of an oily liquid, to which the name 'amylic alcohol' has been given. This substance has the composition $C_5H_{12}O$ (or $C_5H_{11}—O—H$); it yields water and a compound ether when treated with an acid, for instance:

$$\underset{\text{Amylic Alcohol.}}{C_5H_{11}—O—H} + \underset{\text{Hydrochloric Acid.}}{HCl} = \underset{\text{Water.}}{H—O—H} + \underset{\text{Chloride of Amyl.}}{C_5H_{11}Cl.}$$

When oxidised by means of a mixture of sulphuric acid and bichromate of potash, it is converted by the loss of two atoms of hydrogen into $C_5H_{10}O$, which is easily oxidised to valerianic acid, $C_5H_{10}O_2$, an acid also obtained from the plant 'valerian,' whence its name.

Polyatomic Alcohols and their Derivatives.—Chloride of methyl, which is the hydrochloric ether of methylic alcohol, can also be obtained by the action of chlorine upon marsh gas ($CH_4 + Cl_2 = CH_3Cl + HCl$); and similarly, the chloride of ethyl, the chloride of amyl, &c. can be obtained by the action of chlorine upon the corresponding hydrocarbons, C_2H_6; C_5H_{12}; &c. We have thus a relation between the class of alcohols which we have just been considering, and compounds of carbon, hydrogen, and *one* atom of chlorine. Now there are other classes of alcohols which stand in a similar relation to certain compounds of carbon and hydrogen with *two or more* atoms of chlorine. It will be sufficient for our present purpose to give a few examples of such alcohols. Olefiant gas (see p. 324) unites with its own volume of chlorine gas to form a colourless volatile liquid, sparingly soluble in water, called chloride of ethylene, or 'oil of Dutch chemists,' because it was discovered by four Dutch chemists. This substance has the formula $C_2H_4Cl_2$, and is formed by the union of C_2H_4 and Cl_2. It has many points of analogy with such a metallic chloride as chloride of lead, $PbCl_2$, just as chloride of ethyl resembles in many respects chloride of sodium, NaCl. Thus, if chloride of lead is treated with acetate of silver, we get chloride of silver and acetate of lead; and similarly, chloride of ethylene with acetate of silver gives us chloride of silver and acetate of ethylene; and by acting on acetate of ethylene with caustic potash, we obtain acetate of potash and hydrated oxide of ethylene; just as acetate of lead and caustic potash yield acetate of potash and hydrated oxide of lead. Hydrated oxide of lead is $H—O—Pb—O—H$, and hydrated oxide of ethylene is $H—O—C_2H_4—O—H$. Here ethylene (C_2H_4) is a dyad radical, and its hydrated oxide (which, from its sweet taste, has been called glycol) is a diatomic alcohol. Glycol forms compound ethers with acids, and just as in the case of lead we have normal and basic salts, so from glycol we can obtain normal and basic ethers; $C_2H_4Cl_2$ or $Cl—C_2H_4—Cl$, and $H—O—C_2H_4—Cl$ may be given as examples. When oxidised, glycol yields, among other products, its aldehyd, 'glyoxal' ($C_2H_2O_2 = C_2H_6O_2 — 2H_2$), which is easily oxidised to form oxalic acid, $C_2H_2O_4$. Oxalic acid is a white crystalline solid, readily soluble in water. As crystallised from its aqueous solution, it contains two molecules of water of crystallisation. It has an intensely sour taste, and is very poisonous. It is produced in the oxidation of very many organic substances; thus, when sugar is boiled with nitric acid, much oxalic acid is formed. It is now usually prepared by heating sawdust (impure cellulose) with caustic potash—hydrogen is given off, and oxalate of potash ($C_2K_2O_4$) formed; from this, oxalic acid can be obtained. Oxalic acid is a dibasic acid (see p. 317). Its most important salts are: Acid oxalate (binoxalate) of potash, or 'salt of sorrel,' C_2HKO_4, which occurs in the juice of various kinds of sorrel; oxalate of lime (C_2CaO_4).

Glycerine, a substance of great importance, the preparation of which will be described presently, is an example of a triatomic alcohol. Its formula is

$$C_3H_8O_3 \text{ or } C_3H_5\begin{cases}—O—H\\—O—H\\—O—H\end{cases}$$

Here the radical C_3H_5 is triad, like bismuth in $Bi(OH)_3$. Accordingly, glycerine forms with acids compound ethers, of which there are three series, which we may represent by the examples $C_3H_5Cl_3$, $C_3H_5Cl_2(OH)$, and $C_3H_5Cl(OH)_2$. Erythromannite, a sweet substance obtained from certain lichens, is an example of a tetratomic alcohol ($C_4H_{10}O_4$ or $C_4H_6(OH)_4$); and mannite, a sweet crystalline substance found along with sugar in the manna, or sweet exudation from the ash-tree, is an example of a hexatomic alcohol. The formula of mannite is $C_6H_{14}O_6$ (or $C_6H_8(OH)_6$), and differs from that of grape-sugar by containing two atoms of hydrogen more; and grape-sugar (especially levulose, p. 332) can be converted into mannite by treating it with nascent hydrogen.

FATS AND OILS.

Soap.—If pure acetic acid and glycerine be mixed together and heated, the product will be found to be different according to the temperature and the proportion in which the two substances are mixed. If the temperature does not rise above 212° F. the reaction takes place in accordance with the equation:

$$\underset{\text{Glycerine.}}{C_3H_5\begin{cases}OH\\OH\\OH\end{cases}} + \underset{\text{Acetic Acid.}}{H—C_2H_3O_2} = \underset{\text{Water.}}{H—O—H} + \underset{\text{Monoacetine.}}{C_3H_5\begin{cases}C_2H_3O_2.\\OH.\\OH.\end{cases}}$$

If sufficient acetic acid is present, and the temperature is raised to 480° F. a more complete action of exactly the same kind takes place, thus:

$$\underset{\text{Glycerine.}}{C_3H_5\begin{cases}OH\\OH\\OH\end{cases}} + \underset{\text{Acetic Acid.}}{\begin{matrix}H—C_2H_3O_2\\H—C_2H_3O_2\\H—C_2H_3O_2\end{matrix}} = \underset{\text{Water.}}{\begin{matrix}H—O—H\\H—O—H\\H—O—H\end{matrix}} + \underset{\text{Triacetine.}}{C_3H_5\begin{cases}C_2H_3O_2.\\C_2H_3O_2.\\C_2H_3O_2.\end{cases}}$$

When the conditions are intermediate, diacetine $\left(C_3H_5\begin{cases}C_2H_3O_2\\C_2H_3O_2\\OH\end{cases}\right)$ is formed.

Monoacetine and diacetine are *basic* compound ethers of glycerine; while triacetine is a *normal* compound ether. Now, the fats and fixed or greasy oils, which are found in such abundance in

many seeds, and in the cellular tissue of animals, are all *normal compound ethers of glycerine*, constituted like triacetine; such compounds are called 'glycerides.' As triacetine is formed by the union of glycerine and acetic acid and the simultaneous separation of water, so we can reverse the process, and by heating triacetine with a large quantity of superheated steam, add water to it, and obtain glycerine and acetic acid. The fats and oils treated in the same way yield glycerine and one or more 'fatty or oily acids.' A similar decomposition takes place, but much more readily, when the fat or oil is treated with caustic potash or caustic soda. In this case, of course, we obtain, not the acid, but its potash or soda salt, and as the potash and soda salts of the fatty and oily acids are *soaps*, this process is called 'saponification,' or soap-making; and a fat or oil is said to be 'saponified' when it is treated with a caustic alkali. In order to separate the soap thus produced from the glycerine formed at the same time, common salt is added to the liquid, when the soap, being insoluble in brine, separates as a curdy solid, leaving the glycerine dissolved. 'Hard soap' has soda, 'soft soap' potash, as base.

The most important 'glycerides' are stearine, palmitine, oleine, and linoleine, which are normal compound ethers of glycerine and stearic, palmitic, oleic, and linoleic acids, respectively. Stearine and palmitine are white solids, melting at 160° F. and 142° F. respectively. Oleine and linoleine are liquids. The ordinary fats, such as suet, lard, tallow, &c. are mixtures of stearine, palmitine, and oleine in various proportions; the harder and less fusible containing most stearine; the softer and more fusible containing most oleine. Olive-oil contains palmitine and oleine; almond-oil, oleine with a small quantity of palmitine. Linoleine occurs in linseed-oil, poppy-oil, hemp-seed oil, and other 'drying oils;' when exposed to the air, it absorbs oxygen, and is converted into a solid varnish. Castor-oil consists almost entirely of ricinoleine, the glyceride of ricinoleic acid. The composition of these fatty and oily acids is given in the following table:

Palmitic Acid	$C_{16}H_{32}O_2$.
Stearic Acid	$C_{18}H_{36}O_2$.
Oleic Acid	$C_{18}H_{34}O_2$.
Linoleic Acid	$C_{16}H_{28}O_2$.
Ricinoleic Acid	$C_{18}H_{34}O_3$.

ORGANIC ACIDS.

We have already mentioned a considerable number of organic acids—namely, acetic, lactic, formic, valerianic, oxalic, stearic, palmitic, oleic, linoleic, and ricinoleic. We shall here name, and very shortly describe a few more.

Succinic Acid, $C_4H_6O_4$, a dibasic acid, obtained by the distillation of amber, by the oxidation of fatty acids, and by the reduction of malic and of tartaric acids.

Malic Acid, $C_4H_6O_5$, a dibasic acid, obtained from the juice of sour apples, currants, rowan-berries, rhubarb, &c.

Tartaric Acid, $C_4H_6O_6$, a dibasic acid. Acid tartrate of potash, $C_4H_5KO_6$, occurs in the juice of the grape. This salt is somewhat sparingly soluble in water, and still less soluble in dilute alcohol; it is therefore deposited as a crystalline crust when the grape-juice is fermented. This crust, which contains, besides bitartrate of potash, tartrate of lime, and colouring-matter, is called tartar or argol. Purified by recrystallisation, it is known as cream of tartar. Tartaric acid is obtained from it by first converting it into tartrate of lime, and decomposing this by sulphuric acid. Tartar emetic is prepared by dissolving antimonious oxide (Sb_2O_3) in a solution of cream of tartar.

Citric Acid, $C_6H_8O_7$, a tribasic acid, occurs in the juice of the orange, lemon, citron, and, along with malic acid, in the currant, gooseberry, raspberry, and many other fruits. It is prepared by neutralising the acid juice with lime, and decomposing the citrate of lime by means of sulphuric acid.

When citric acid is heated, it loses water, and is converted into *aconitic acid*, $C_6H_6O_6$, a tribasic acid, also obtained from the aconite plant, whence its name.

Benzoic Acid, $C_7H_6O_2$, a monobasic acid, is contained in gum-benzoin, and is obtained from it by sublimation. Oil of bitter almonds is a mixture of prussic acid and benzoic aldehyd (C_7H_6O). Benzoic acid when distilled with lime yields *benzol*, C_6H_6; thus, $C_7H_6O_2 + CaO,H_2O = C_6H_6 + CaO,CO_2 + H_2O$.

Gallic Acid, $C_7H_6O_5$, a monobasic acid obtained by the fermentation of the tannin of nut-galls. It produces, when mixed with solutions of ferric salts, a deep blue-black precipitate, which is the basis of ordinary writing ink. With ferrous salts, it produces a white precipitate, which becomes black, owing to oxidation, when exposed to the air.

Tannin or *Tannic Acid*.—This name is applied to a number of substances occurring in nut-galls, oak-bark, catechu, kino, cinchona bark, &c. and having the property of forming an insoluble compound with gelatine.

Uric Acid, $C_5H_4N_4O_3$, a dibasic acid, occurs as urate of soda, and urate of ammonia in the excrements of birds and reptiles, in small quantity in the urine of other animals, in some urinary calculi, and in the 'chalk-stones' which form in the joints of gouty persons. Urate of ammonia forms a large part of guano.

Prussic Acid or *Hydrocyanic Acid*.—If nitrogen gas is passed through a heated mixture of charcoal and caustic potash, carbonic oxide, hydrogen, and a substance having the composition KCN, are formed, thus:

$$2KHO + 4C + N_2 = 2KCN + 2CO + H_2.$$

The potassium in this compound may be replaced by other metals, thus: $KCN + AgNO_3 = AgCN + KNO_3$, and $KCN + HCl = HCN + KCl$. There is thus a series of compounds in which the group CN acts as a monad salt-radical—plays, in fact, the part of Cl. This radical is called cyanogen, and its compounds, cyanides. HCN is hydrocyanic (or prussic) acid; KCN, cyanide of potassium; and so on. Almost all cyanogen compounds are prepared from the substance known as 'yellow prussiate of potash,' or 'ferrocyanide of potassium.' This salt has the composition $4KCN,Fe(CN)_2$, and may be regarded as a compound of cyanide of potassium and ferrous cyanide. It is formed by fusing animal refuse containing nitrogen (such as dried blood, parings of horn, hide, &c.) along with caustic potash and iron, exhausting the mass with water in the presence of air, and concentrating the clear solution, when the

salt crystallises out in large tabular crystals containing two molecules of water of crystallisation. In the fusion, cyanide of potassium is formed by the union of the nitrogen and carbon of the animal matter with the potassium of the potash; and the cyanide of potassium, by the action of water, oxygen, and iron, is converted into the ferrocyanide, thus: $6KCN + Fe + H_2O + O = 2KHO + 4KCN,Fe(CN)_2$. Ferrocyanide of potassium, when treated with dilute sulphuric acid, yields hydrocyanic acid, which, being volatile, can be distilled off from the residue, consisting of sulphate of potash and a substance called 'Everitt's salt.'

Prussic acid is an extremely poisonous substance, and this character belongs also to most of the cyanides. The ferrocyanides are, however, exceptions. By the action of chlorine, ferrocyanide of potassium is converted into ferricyanide of potassium or red prussiate of potash, $4KCN,Fe(CN)_2 + Cl = 3KCN,Fe(CN)_3 + KCl$. The most important cyanides are: Cyanide of potassium, KCN; cyanide of silver, $AgCN$; mercuric cyanide, $Hg(CN)_2$, formed by dissolving mercuric oxide in aqueous hydrocyanic acid, and crystallising. Ferrocyanide and ferricyanide of potassium. Ferric ferrocyanide (Prussian blue) and ferrous ferricyanide (Turnbull's blue). Mercuric cyanide, when heated, decomposes into metallic mercury and cyanogen. Part of the cyanogen passes off as cyanogen gas, $(CN)_2$ or C_2N_2, part remains as brown solid of the same composition, known as paracyanogen. Just as chlorine, when passed into a cold solution of caustic potash, gives chloride of potassium, and hypochlorite of potash, KCl and $KClO$, so cyanogen, under the same conditions, gives cyanide of potassium, KCN, and cyanate of potash, $KCNO$. Cyanate of potash can also be formed by the oxidation of cyanide of potassium by means of red oxide of lead or black oxide of manganese.

ORGANIC BASES.

It has already been pointed out that the alcohols have a great resemblance in their mode of action upon acids to hydrated bases (p. 333); but there are other organic compounds which are much more completely analogous to the bases of inorganic chemistry, forming, with acids, salts, which are usually crystalline, and which undergo double decomposition exactly as the salts of metallic oxides do. Many of these organic bases, or alkaloids, as they are called, are soluble in water, and have an alkaline reaction. Some of them can be formed artificially, and some occur as salts in the juices of various plants. Thus, in opium, the dried juice of the unripe heads of the white poppy (*Papaver somniferum*), there occur salts of morphia, codeia, narcotine, thebaine, papaverine, narceine, and some other less completely investigated alkaloids. The juice of the deadly nightshade (*Atropa belladonna*) contains a salt of the alkaloid atropia. Nux-vomica contains salts of strychnia and brucia; cinchona bark, salts of quina and cinchona; henbane (*Hyoscyamus niger*) contains a salt of hyoscyamine; tobacco (*Nicotiana tabacum*) contains a salt of nicotine; hemlock (*Conium maculatum*), a salt of conia; and so on. In most cases, the plant owes its special action on the animal system, as a poison or drug, to the alkaloid or alkaloids contained in it, so that it is possible to substitute a salt of the alkaloid as a medicine for the extract or tincture of the plant, with the advantage of having a substance of constant composition and action, instead of a mixture which sometimes contains more, sometimes less, of the alkaloid which is its really active ingredient.

For detailed accounts of these vegetable alkaloids, we must refer the reader to the larger handbooks of chemistry. They all contain nitrogen, and may be regarded as ammonia in which the hydrogen has been replaced by organic radicals; thus, trimethylamine, a base which occurs in herring-brine, is $N(CH_3)_3$, corresponding to ammonia, NH_3. The other natural bases have a similar, though, in most cases, a much more complicated constitution.

VOLATILE OR ESSENTIAL OILS

are obtained from many plants by distillation with water, the oil coming over with the water, and collecting in the receiver, partly dissolved in the water, partly floating upon its surface. The watery solution has the odour of the oil. In this way, oil (or *attar*) of roses and rose-water, oil of lavender and lavender water, &c. are prepared. Many of these oils, so different in odour, have the same composition as oil of turpentine—namely, C_5H_8. Of these we may name—oil of lemons, of bergamot, of juniper, of thyme, of parsley. Others contain various volatile substances. Thus, oil of bitter almonds is a mixture of benzoic aldehyd (C_7H_6O) and prussic acid; oil of meadow-sweet is salicylic aldehyd ($C_7H_6O_2$); oil of mustard, C_4H_5NS.

ALBUMINOUS OR PROTEIN COMPOUNDS.

The white of egg consists chiefly of a watery solution of a substance called *albumine;* a similar substance occurs in the serum of blood and in dropsical fluids. *Fibrine* occurs in the clot of blood; *caseine* is that constituent of milk which is curdled by rennet or by the addition of an acid to the milk. These substances have many properties in common, and have nearly the same composition. We now know a considerable number of such bodies. They form essential constituents of animal organisms, and also occur in plants. They are *produced* in the plant from simpler substances. In the animal system they are never formed, but only undergo transformation. They are thus necessary ingredients in the food of animals (see HUMAN PHYSIOLOGY). They exist both in the soluble and in the insoluble condition, and are easily changed from the one to the other. Thus, albumine occurs in solution in white of egg, but when the egg is boiled, the albumen becomes insoluble. Caseine is in solution in milk, but when the milk is curdled, the caseine is rendered insoluble. By the process of digestion in the stomach, insoluble albuminous substances are rendered soluble, and capable of being absorbed. These albuminous substances have an extremely complex composition, and chemists are not yet able to give *formulæ* for them. Analysis gives the following results:

Carbon	52·7	to	54·5	per cent.
Hydrogen	6·9	"	7·3	"
Nitrogen	15·4	"	16·5	"
Oxygen	20·9	"	23·5	"
Sulphur	0·8	"	1·6	"

CHEMISTRY APPLIED TO THE ARTS.

ALMOST every branch of manufacture involves to a greater or less extent chemical principles, so that a complete treatise on chemical technology should contain an account of nearly every manufacturing process, and a discussion of the chemical actions taking place in each. It is obvious that nothing of this kind can be attempted here. We shall confine ourselves to a statement of the chemical principles involved in a few of the more important chemical manufactures, excluding, of course, those to which separate papers are devoted in this series, or which have been sufficiently explained in the article CHEMISTRY.

It is scarcely possible to adopt anything like a systematic arrangement of this subject, but we shall endeavour to keep, as far as possible, allied manufactures together, and to proceed from the less to the more complex. The reader is expected to possess an elementary knowledge of chemistry, such as might be acquired by the study of the paper on CHEMISTRY.

We shall first consider the preparation of sulphuric acid, as that is the starting-point of a large number of chemical manufactures.

Anhydrous sulphuric acid (SO_3) can be prepared by heating certain sulphates. Thus, if bisulphate of soda (H_2O,SO_3,Na_2O,SO_3 or $HNaSO_4$) is heated, it loses water, and is converted into what is called anhydrous bisulphate of soda (Na_2O,SO_3,SO_3). When this substance is very strongly heated, it gives off anhydrous sulphuric acid, and normal sulphate of soda is left. The ferric sulphates are decomposed by heat into ferric oxide and anhydrous sulphuric acid. Thus, $Fe_2O_3,3SO_3 = Fe_2O_3 + 3SO_3$; and a similar decomposition takes place with basic ferric sulphates. Thus, $Fe_2O_3,2SO_3 = Fe_2O_3 + 2SO_3$. It is upon this latter decomposition that the preparation of 'Nordhausen' or 'Saxon' sulphuric acid depends.

Green vitriol or ferrous sulphate has the composition $FeSO_4,7H_2O$ or $FeO,SO_3,7H_2O$; when exposed to heat and air, it absorbs oxygen, and is converted into basic ferric sulphate; thus, $2(FeO,SO_3) + O = Fe_2O_3,2SO_3$, the water of crystallisation being given off. If the oxidation and drying were complete, on distilling the product nothing would be given off but anhydrous sulphuric acid. But in practice this is not so; some water is always left, so that some hydrated sulphuric acid (H_2O,SO_3 or H_2SO_4) is formed, and some ferrous sulphate (FeO,SO_3) is always left unoxidised, which undergoes the following decomposition: $2(FeO,SO_3) = Fe_2O_3 + SO_3 + SO_2$, half of the SO_3 losing oxygen, so as to convert $2FeO$ into Fe_2O_3. The result, therefore, is, that ferric oxide (Fe_2O_3) is left behind, and sulphurous acid (SO_2), anhydrous sulphuric acid (SO_3), and hydrated sulphuric acid (H_2O,SO_3 or H_2SO_4) pass over. The latter unite to form 'fuming' or 'Nordhausen' sulphuric acid ($H_2O,2SO_3$ or $H_2S_2O_7$). The distillation is performed in earthenware retorts, arranged in rows in a furnace, and earthenware jars are used as receivers. This mode of preparing sulphuric acid from 'green vitriol' gave rise to the name 'oil of vitriol,' now generally given to hydrated sulphuric acid.

But by far the largest part of the sulphuric acid of commerce is prepared from sulphurous acid.

The sulphurous acid is made either by burning sulphur ($S + O_2 = SO_2$), or, more commonly, by burning iron pyrites (FeS_2). When this mineral is heated in presence of air, it burns, giving out a great deal of heat, and forms ferric oxide and sulphurous acid; thus, $2FeS_2 + 7O = Fe_2O_3 + 2SO_2$. The sulphurous acid gas, prepared in either way, is led by a wide pipe into a series of large chambers lined with lead, into which nitric acid, atmospheric air, and steam, are also conducted. The action which takes place is represented by the following equations:

$$(1.)\ 3SO_2 + H_2O,N_2O_5 + 2H_2O = 3(H_2O,SO_3) + 2NO.$$

The sulphuric acid (H_2O,SO_3) falls down as a fine rain to the bottom of the chamber, while the nitric oxide (NO) (see CHEMISTRY) immediately unites with oxygen from the air to form peroxide of nitrogen, thus:

$$(2.)\ NO + O = NO_2.$$

The peroxide of nitrogen then acts on sulphuric acid and water, thus:

$$(3.)\ NO_2 + H_2O + SO_2 = NO + H_2O,SO_3.$$

The sulphuric acid thus formed falls to the floor of the chamber, and the nitric acid (NO) unites with oxygen from the air, as in (2). If atmospheric air is admitted in sufficient quantity, the actions (2) and (3) go on continuously, a limited quantity of oxide of nitrogen being able to convert an unlimited quantity of sulphurous acid and water into sulphuric acid; the nitrogen oscillating between two states of oxidation, NO and NO_2, the latter giving oxygen to the sulphurous acid, and the former taking oxygen from the air. The gas in the chambers, therefore, becomes poorer in sulphurous acid and oxygen as it proceeds onwards, until at last it contains no sulphurous acid, and consists almost entirely of nitrogen from the atmospheric air and of peroxide of nitrogen. As will be presently seen, the gas leaving the chambers should contain no nitric oxide, and to insure this, there should be a little oxygen. It is obvious that if the peroxide of nitrogen can be extracted from the effluent gas, it may be used over again to effect the oxidation of a new quantity of sulphurous acid. This extraction is effected in the following way: Peroxide of nitrogen is soluble in *strong*, but not in *dilute* sulphuric acid. The effluent gas is, therefore, sent up a tower, or wide chimney, which is packed with fragments of coke. Down this tower a stream of strong sulphuric acid is poured, trickling through the coke. The gas is thus freed from the peroxide

of nitrogen, and only atmospheric nitrogen, with any excess of oxygen which may be present, escapes at the top of the tower. As nitric oxide is not soluble in sulphuric acid, it would also escape, and thus be lost, if it were not all converted into peroxide of nitrogen before leaving the last chamber. The solution of peroxide of nitrogen is conducted back to the first chamber, where the actions (3) (2) are again commenced. It will be seen that, theoretically, a given quantity of nitric acid should be able to convert an unlimited quantity of sulphurous acid, water, and oxygen, into sulphuric acid. In practice, however, this is not the case, and it is necessary to supply new nitric acid from time to time to compensate for loss. This loss occurs (not to speak of accidental leakage) from two causes: 1. Part of the nitric oxide, even in the presence of excess of oxygen, is reduced to nitrous oxide (N_2O), which, not being directly oxidisable, takes no further part in the action, and escapes with the nitrogen from the top of the tower. 2. The sulphuric acid on the floor of the chamber, although not strong enough to dissolve peroxide of nitrogen, dissolves some *nitric acid*, which is removed with it from the chamber. The admission of steam to the chambers must be so regulated, that the sulphuric acid on the floor has the specific gravity 1·5, which corresponds to 60 per cent. of hydrated sulphuric acid (H_2O,SO_3), and 40 per cent. water. If the acid is stronger than this, the oxidation does not take place regularly; and if it is weaker, it dissolves sulphurous acid. The 'chamber acid' is concentrated by heating it in glass or platinum vessels, until it has a specific gravity 1·83, corresponding to about 92 per cent. of hydrated sulphuric acid. The concentration can be carried on up to specific gravity 1·75 in lead vessels; acid stronger than this acts rapidly on lead at high temperatures.

Sulphuric acid thus prepared contains various impurities: 1. Sulphate of lead, derived from a slight action on the lead of the chambers, or on the lead-pan used for concentration; sulphate of lead, being insoluble in dilute sulphuric acid, is precipitated as a white powder when sulphuric acid containing it is mixed with water. 2. Nitric acid. 3. Arsenic, derived from the iron pyrites, which always contains traces of arsenic. Sulphuric acid prepared from *sulphur* does not contain arsenic.

MANUFACTURE OF SODA.

Carbonate of soda occurs naturally in Hungary, North Africa, and Mexico. It is found either as a crystalline crust, left by the evaporation of the water of lakes containing the salt in solution, or mixed with earth. In the latter case, the earth is exhausted with water, and the solution evaporated. The North African soda, from Egypt and Fezzan, has been long known under the names 'natron' and 'trona.' It is the substance mentioned in the Bible (Proverbs xxv. 20; Jeremiah ii. 22) as nitre: the reader will see, on referring to the passages, that the meaning becomes at once clear if we read 'washing-soda,' instead of 'nitre.'

Another long-known source of soda is the ash of certain plants. Just as most land-plants contain organic salts of potash, which, when the plants are burnt, are converted into carbonate of potash, which can be extracted from the ash—so sea-weeds and some plants growing on the sea-shore contain organic salts of soda, and in precisely the same way their ashes yield carbonate of soda. 'Barilla' is the crude carbonate of soda obtained in Spain from the ash of the sea-side plant, *Salsola soda;* and in France, 'salicor' and 'blanquette' are similarly obtained from the ashes of *Salicornia annua* and other shore-plants. 'Kelp,' the ash of various sea-weeds gathered and burnt on the northern and western shores of Scotland and Ireland, also contains carbonate of soda, but is chiefly prepared on account of the iodides contained in it (see CHEMISTRY).

But by far the greater part of the soda of commerce is prepared from common salt (chloride of sodium), by what is called, from its inventor, 'Leblanc's process.'

The salt is first heated with sulphuric acid, and thus converted into sulphate of soda; the hydrochloric acid evolved being condensed in coke towers, down which a stream of water flows:

$$NaCl + H_2SO_4 = HCl + NaHSO_4 \text{ and}$$
$$NaCl + NaHSO_4 = HCl + Na_2SO_4.$$

(See CHEMISTRY.) The sulphate of soda, known as 'salt-cake,' is then mixed with coal and limestone in the proportion of about 2 parts salt-cake, 2 limestone, and rather more than 1 coal. The mixture is heated in a reverberatory furnace, and thoroughly stirred with an iron instrument. After about an hour's heating, it is removed, and allowed to cool. In this state it is called 'black ball.' The precise course of the chemical change is not yet certainly ascertained, but the final result is, that the 'black ball' consists chiefly of carbonate of soda and a compound of lime with sulphide of calcium ($3CaS,CaO$), along with some caustic soda and charcoal. By treatment with water, the carbonate of soda and caustic soda are dissolved, while the oxysulphide of calcium and the charcoal are left behind. The clear solution is then evaporated, and the dried residue is known in commerce as 'soda-ash.'

'Soda crystals,' or 'washing-soda,' is prepared from soda-ash by dissolving it in hot water, and allowing the solution to crystallise, when nearly pure carbonate of soda crystallises out with 10 molecules of water of crystallisation ($Na_2O,CO_2,10H_2O$ or $Na_2CO_3,10H_2O$), almost all the impurities remaining in the mother-liquor (see CHEMISTRY). 'Bicarbonate of soda,' or 'baking-soda,' is prepared by treating soda crystals with carbonic acid gas.

The residue left, on dissolving out the carbonate of soda from the 'black ball,' consisting chiefly of oxysulphide of calcium (the compound of lime and sulphide of calcium), is called 'soda-waste,' and has long been a source of great annoyance to soda manufacturers and their neighbours. It accumulates in vast mounds round the works, and gives off sulphuretted hydrogen whenever acid liquids come in contact with it.

There are now various methods in use by which the sulphur is recovered from the waste, so that it can be used again in the manufacture of sulphuric acid.

These methods are in principle the same, and consist in the oxidation of the waste by means of atmospheric oxygen, and in the precipitation of

the sulphur from the solution of the oxidised waste by means of hydrochloric acid.

Caustic Soda is formed from soda-ash by dissolving it in water, and adding slaked lime, when carbonate of lime falls as an insoluble white powder, leaving caustic soda in solution. This solution is either used as such, or boiled down to a solid mass. The action is:

$$Na_2O,CO_2 + CaO,H_2O = Na_2O,H_2O + CaO,CO_2 \text{ or}$$
$$\underset{\text{Carbonate of Soda.}}{Na_2CO_3} + \underset{\text{Slaked Lime.}}{CaH_2O_2} = \underset{\text{Caustic Soda.}}{2NaHO} + \underset{\text{Carbonate of Lime.}}{CaCO_3}.$$

Caustic soda is also often prepared direct from the 'black ball,' which, for this purpose, is made from a mixture containing a larger quantity of coal than is used for preparing soda-ash.

Bleaching-powder.—Slaked lime readily absorbs chlorine gas, forming a substance called 'chloride of lime,' or bleaching-powder. This substance may be regarded as a mixture, or compound of chloride of calcium ($CaCl_2$), hypochlorite of lime (CaO,Cl_2O or $CaCl_2O_2$), and slaked lime (CaO,H_2O). Exposed to the air, it gives off hypochlorous acid, the hypochlorite of lime being decomposed by the carbonic acid of the air. When treated with sulphuric acid, sulphate of lime is formed; and if only so much acid is added as is required to neutralise the slaked lime, and decompose the hypochlorite, hypochlorous acid is given off; but if a larger quantity of acid is added, the chloride of calcium is also decomposed, and the hydrochloric acid produced in this decomposition acts on the hypochlorous acid, and produces chlorine:

$$2HCl + Cl_2O = H_2O + 2Cl_2.$$

Other strong acids act in the same way.

BLEACHING.

The bleaching of vegetable or animal fibre, yarn, or cloth, consists in the destruction or removal of the colouring-matter naturally accompanying the fibre, so as to leave the latter white. Along with this, we may conveniently consider the discharging—that is, removal or destruction of colouring-matter artificially added to the fibre. In bleaching vegetable fibres, or the yarn or cloth made from them, two distinct things have to be attended to—first, the removal of fatty or oily matters, either originally present, or introduced in the processes of spinning or weaving; and second, the destruction of those colouring-matters which are not removed along with the oil. The removal of the oil is effected by boiling with alkalies—by which a soap is formed (see p. 349), which is washed out with water. This washing removes along with the soap the dirt which the oil kept fixed to the fibre. There still, however, remains a yellowish colouring-matter, which must be destroyed if the cloth is to be rendered quite white. This may be done either by the old process of grass-bleaching, in which the cloth is spread in a moist state upon grass, and exposed for several days to the action of the air, or by means of wet chlorine or hypochlorous acid. In either case, the colouring-matter is destroyed by *oxidation*. In grass-bleaching it is probable that the oxidation of the colouring-matter is caused by the *ozone* (see CHEMISTRY) that is present in the air.

In order to understand how chlorine along with water can act as an oxidising agent, we must recollect that chlorine and hydrogen readily enter into combination to form hydrochloric acid. If a solution of chlorine gas in water is exposed to light, the chlorine slowly displaces the oxygen—hydrochloric acid is formed, and oxygen is set free. Now, this decomposition of water takes place only slowly, and only when the mixture is exposed to bright light, *if no oxidisable substance is present.* But very many oxidisable substances, even such as are not easily oxidised by means of free oxygen, assist the chlorine to decompose the water; so that, the constituents of the water being, so to speak, pulled in opposite directions, the chlorine takes the hydrogen, forming hydrochloric acid, and the oxidisable substance is oxidised. It is in this way the chlorine bleaches, and it will be at once seen that water is essential in the process. This can easily be shewn by placing a piece of cloth, dyed with a vegetable colour—turkey-red, for instance—in a jar of chlorine gas; if part of the cloth be wet with water, and part left dry, it will be found that, in a few minutes, the wet parts have become white, while the dry parts remain red. Hypochlorous acid acts also as a bleaching agent, by oxidising the colouring-matter, $Cl_2O + H_2O$ becoming $2HCl + O_2$—the oxygen not being given off as gas, but acting upon the colouring-matter. Most vegetable colouring-matters are converted by such oxidation into colourless substances; or, at all events, are rendered soluble in water, so that they can be washed away.

In practice, cotton cloth, after having been boiled in alkaline solutions, and washed, is soaked in a very dilute solution of bleaching-powder, and then 'soured'—that is, passed through water containing a small quantity of acid (sulphuric or hydrochloric). The acid, acting on the bleaching-powder, produces chlorine, which bleaches the cloth in the way explained above. The excess of chlorine, or hypochlorous acid, must be got rid of, as, if left long in contact with the cloth, it injures the fibre. This is done by means of washing with water, or by treating the cloth with what is technically called an 'antichlor'—that is, some substance which will convert the chlorine into a harmless compound. Sulphite of soda and hyposulphite of soda are the substances mostly used for this purpose. They are oxidised by the moist chlorine, the chlorine becoming hydrochloric acid, which can be neutralised by an alkali and washed out.

Chlorine and hypochlorous acid are not only used to bleach cloth or vegetable fibre, but also to discharge colours with which the cloth has been dyed. If this discharging is confined to definite parts of the cloth, a white pattern can be produced on a coloured ground. This is effected by printing the pattern on the cloth with a mixture of tartaric or citric acid and gum. The cloth is then passed through a dilute solution of bleaching-powder, when the acid sets free chlorine upon the parts printed; and by the oxidising action explained above, the colour is discharged from these parts.

Animal fibres (silk, wool) cannot be bleached by means of chlorine, as that substance exerts a destructive action upon them. The only materials used in bleaching wool and silk are water, soap, carbonate of soda, and sulphurous acid.

COLOURING-MATTERS.

The object of dyeing is to give a fast colour to animal or vegetable fibres or fabrics made from them. It differs from painting or mere staining in that the colour is fast—that is, so fixed to or in the fibre that it cannot be washed off or out by water or soap. In painting, on the contrary, the colouring-matter is mechanically spread upon the object to be painted. As, however, many colouring-matters are used both in dyeing and in painting, we shall first give a description of the most important colouring-matters, without reference to their special use.

Colouring-matters, among which, for convenience, we have included white paints, may be most conveniently divided into Inorganic and Organic.

Of the Inorganic, the most important are :

White-lead, a basic carbonate of lead, or compound of carbonate of lead and hydrated oxide of lead. Red-lead, an oxide of lead prepared by heating *massicot* (plumbic oxide) in a current of air. Chromate of lead (PbO,CrO_3), known as chrome yellow, is prepared by precipitating a soluble salt of lead, usually the acetate, by means of chromate of potash, or by acting upon solid carbonate, chloride, or sulphate of lead with chromate of potash. Basic chromate of lead ($2PbO,CrO_3$), chrome red, is prepared by the action of caustic alkalies upon chrome yellow, by treating chrome yellow, suspended in water with finely divided oxide of lead, or by fusing chrome yellow with nitre. Oxide of zinc (ZnO), zinc white, is used as a paint instead of white-lead in places exposed to the action of sulphuretted hydrogen. Sulphuretted hydrogen converts white-lead into the black sulphide of lead, but does not affect the colour of zinc white. Sulphide of cadmium (CdS), cadmium yellow, *jaune brilliant;* sesquioxide of chromium, or chromic oxide (Cr_2O_3), chrome green ;* sesquioxide of iron, or ferric oxide (Fe_2O_3), Venetian red. Ferric oxide is also deposited in cloth for the purpose of dyeing it buff; hydrated ferric oxide is the colouring-matter of ochre and umber. Peroxide of manganese is not used as a pigment, but is deposited in cloth as a black or brown dye (see page 346). Smalt is a blue powder consisting of finely divided glass coloured blue by means of silicate of cobalt. Cobalt ultramarine, or Thénard's blue, is a compound of oxide of cobalt with alumina, in which the alumina plays the part of an acid. Stannate of cobalt (CoO,SnO_2) is also used as a blue pigment. Cobalt green is a compound of oxide of cobalt with oxide of zinc. Cobalt yellow is a double nitrite of cobalt and potash. Brunswick green is a basic carbonate of copper (CuO,CO_2,CuO,H_2O). Bremen blue is hydrated oxide of copper (CuO,H_2O); when mixed with linseed-oil it becomes green, from the formation of linoleate of copper. Scheele's green is arsenite of copper. Schweinfurt (or emerald) green is a compound of acetate of copper and arsenite of copper. Normal acetate and various basic acetates of copper occur in commerce under the name of verdigris. Vermilion is mercuric sulphide (HgS). When mercury and sulphur are mixed together, a black compound is formed, which, when sublimed, is converted, without change of composition, into a beautiful scarlet substance, vermilion. The same change is produced when the black mercuric sulphide is digested with a solution of an alkaline sulphide, containing excess of sulphur. Orpiment is arsenious sulphide (As_2S_3), and is prepared by heating together arsenious acid (As_2O_3) and sulphur, or realgar (AsS) and sulphur, or by precipitating a solution of arsenious acid in hydrochloric acid by means of sulphuretted hydrogen. Ultramarine is, properly speaking, a blue pigment, prepared from the blue mineral 'lapis lazuli.' A blue substance is now prepared artificially of a similar composition. It is prepared by heating a mixture of China-clay, soda-ash, sulphate of soda, sulphur and coal. The mass thus obtained is mixed with sulphur and heated in a current of air.

* The name chrome green is sometimes given to a mixture of chrome yellow and Prussian blue.

The organic colouring-matters may be conveniently divided into Artificial and Natural, although it is not always easy to adhere strictly to this classification.

1. *Artificial Organic Colouring-matters.*—Lampblack consists chiefly of carbon mixed with oily and tarry matters; it is prepared by collecting the soot of resin or pitch burned with a supply of air insufficient to oxidise completely the carbon and hydrogen. Prussian blue is ferric ferrocyanide (see CHEMISTRY). It can be prepared by precipitating a solution of ferrocyanide of potassium (yellow prussiate of potash) by means of a solution of a ferric salt (ferric chloride, or muriate of iron, for instance)—this method gives 'neutral' Prussian blue. It can also be prepared by precipitating the solution of yellow prussiate by means of a ferrous salt (such as ferrous sulphate, green vitriol), and oxidising the white precipitate of ferrous ferrocyanide; by this method, what is called 'basic' Prussian blue is formed. Turnbull's blue is ferrous ferricyanide, and is formed by the action of a ferrous salt (green vitriol) on ferricyanide of potassium (red prussiate of potash).

Many very valuable and interesting colouring-matters have been obtained within the last twenty years from coal-tar. We shall shortly describe the preparation of the most important of these. The constituents of coal-tar from which colouring-matters are obtained are : 1. Benzol; 2. Phenol or carbolic acid; 3. Naphthaline; and 4. Anthracene. As these substances boil at different temperatures, they are partially separated from one another when the tar is distilled, and by repeated distillations they can be still further purified. Benzol, as it occurs in commerce, is a mixture of several hydrocarbons, chiefly benzol (C_6H_6, boiling-point 176° F.) and toluol (C_7H_8, boiling-point 226° F.). By the action of nitric acid, benzol and toluol are converted into nitrobenzol and nitrotoluol, thus :

$$\underset{\text{Benzol.}}{C_6H_6} + \underset{\text{Nitric Acid.}}{HNO_3} = \underset{\text{Nitrobenzol.}}{C_6H_5NO_2} + \underset{\text{Water.}}{H_2O.}$$

$$\underset{\text{Toluol.}}{C_7H_8} + \underset{\text{Nitric Acid.}}{HNO_3} = \underset{\text{Nitrotoluol.}}{C_7H_7NO_2} + \underset{\text{Water.}}{H_2O.}$$

As commercial benzol contains both benzol and toluol, of course commercial nitrobenzol contains both nitrobenzol and nitrotoluol. The odour of nitrobenzol resembles very closely that of oil of bitter almonds, and on this account the substance is used in perfumery under the name of artificial oil of bitter almonds, or *Essence de Mirbane.*

Reducing agents convert nitrobenzol and nitrotoluol into 'aniline' and 'toluidine' respectively. In practice, nascent hydrogen from iron and acetic acid is used :

$$\underset{\text{Nitrobenzol.}}{C_6H_5NO_2} + 6H = \underset{\text{Aniline.}}{C_6H_5NH_2} + \underset{\text{Water.}}{2H_2O.}$$

$$\underset{\text{Nitrotoluol.}}{C_7H_7NO_2} + 6H = \underset{\text{Toluidine.}}{C_7H_7NH_2} + \underset{\text{Water.}}{2H_2O.}$$

The mixture of aniline and toluidine obtained from commercial nitrobenzol is known as 'aniline oil.' It is an oily liquid, very slightly soluble in water : from it a great number of colouring-matters are obtained—we shall describe a few of them.

Mauveine.—When aniline is treated with a mixture of bichromate of potash and sulphuric acid, it is blackened, and from the black mass there can be extracted by means of alcohol a violet colouring-matter, called *mauveine*, having the composition $C_{27}H_{24}N$.

Rosaniline.—This substance, from which many of the aniline colours are derived, is formed by the action of various oxidising agents on commercial aniline—that is, upon a mixture of aniline and toluidine, thus :

$$\underset{\text{Aniline.}}{C_6H_7N} + \underset{\text{Toluidine.}}{2C_7H_9N} + 3O = \underset{\text{Rosaniline.}}{C_{20}H_{19}N_3} + \underset{\text{Water.}}{3H_2O.}$$

The oxidising agent usually employed is arsenic acid, which gives up part of its oxygen, and is reduced to arsenious acid (see CHEMISTRY). Rosaniline combines with water to form hydrate of rosaniline, $C_{20}H_{19}N_3,H_2O$, a colourless substance, which, when dissolved in acids, forms salts of rosaniline, having an intense crimson colour. The hydrochlorate and the acetate, $C_{20}H_{19}N_3HCl$ and $C_{20}H_{19}N_3,C_2H_4O_2$, are sold under the name 'fuchsin.'

Violet Impérial, Aniline Blue, Bleu de Paris, Bleu de Lyons, Hofmann's Dahlia, Hofmann's Blue, Aniline Green.—These substances are all derivatives of rosaniline. To understand their constitution, it is necessary that we should first consider the constitution of rosaniline itself. Rosaniline may be regarded as three molecules of ammonia, in which six of the nine atoms of hydrogen have been replaced by organic radicals derived from aniline and toluidine, thus : $C_{20}H_{19}N_3 = N_3\left\{\begin{matrix} C_6H_4 \\ (C_7H_6)_2 \\ H_3 \end{matrix}\right.$ Here C_6H_4 and C_7H_6 are dyad radicals (see CHEMISTRY), derived from benzol ($C_6H_6 = C_6H_4,H_2$) and toluol ($C_7H_8 = C_7H_6,H_2$), and each of these replaces two atoms of hydrogen, so that C_6H_4 and $(C_7H_6)_2$ together replace six atoms of hydrogen in $3NH_3$, leaving three atoms of the hydrogen of the ammonia unreplaced. Thus, in rosaniline, there are, in each molecule, three atoms of hydrogen, occupying the same place as the hydrogen in ammonia does, and similarly related to the nitrogen. Now, it is possible to replace these three atoms (or one, or two of them) by hydrocarbon radicals. If the whole of these are replaced by methyl (CH_3), ethyl (C_2H_5), amyl (C_5H_{11}), phenyl (C_6H_5), or similar radicals, a *blue* colouring-matter is produced. Thus, the 'aniline blue' of De Laire and Girard is $N_3\left\{\begin{matrix} C_6H_4 \\ (C_7H_6)_2 \\ (C_6H_5)_3 \end{matrix}\right.$ or triphenyl rosaniline, and is formed by heating a mixture of aniline and rosaniline. Hofmann's blues are $N_3\left\{\begin{matrix} C_6H_4 \\ (C_7H_6)_2 \\ (C_2H_5)_3 \end{matrix}\right.$ and $N_3\left\{\begin{matrix} C_6H_4 \\ (C_7H_6)_2 \\ (C_5H_{11}) \end{matrix}\right.$ and are formed by heating rosaniline with iodide of ethyl (C_2H_5I) or iodide of amyl ($C_5H_{11}I$). If *one* atom of the hydrogen of rosaniline, which is in the same position as the hydrogen of ammonia, is replaced by a hydrocarbon radical, a reddish purple colouring-matter is formed ; if two of them, the product is bluish purple. Thus, for instance, we have rosaniline, $N_3\left\{\begin{matrix} C_6H_4 \\ (C_7H_6)_2 \\ H_3 \end{matrix}\right.$ the salts of which are red ; methyl rosaniline, $N_3\left\{\begin{matrix} C_6H_4 \\ (C_7H_6)_2 \\ CH_3 \\ H_2 \end{matrix}\right.$ the salts of which are red-purple ; dimethyl rosaniline, $N_3\left\{\begin{matrix} C_6H_4 \\ (C_7H_6)_2 \\ (CH_3)_2 \\ H \end{matrix}\right.$ the salts of which are blue-purple ; and trimethyl rosaniline, $N_3\left\{\begin{matrix} C_6H_4 \\ (C_7H_6)_2 \\ (CH_3)_3 \end{matrix}\right.$ the salts of which are blue. In all these cases the base itself is colourless ; the colour makes its appearance when the base is combined with an acid.

The 'violet impérial' consists of phenyl rosaniline and diphenyl rosaniline ; 'Bleu de Paris,' or 'Bleu de Lyons,' is triphenyl rosaniline ; Hofmann's dahlia is ethyl or amyl rosaniline, and diethyl or diamyl rosaniline.

Cherpin's aniline green is formed by heating aldehyde (see CHEMISTRY) with sulphate of rosaniline ; its composition is represented by the formula $C_{22}H_{27}N_3S_2O$.

Aniline yellow or *aurine* is the hydrochlorate of a base called *chrysaniline.* The formula of the base is $C_{20}H_{17}N_3$; it is obtained from the residues of the manufacture of rosaniline.

Phenol or *carbolic acid* is obtained from that part of the oil of coal-tar which distils over after the benzol. Commercial phenol is a mixture of phenol (C_6H_6O) and cresol (C_7H_8O). It is a white crystalline substance ; unites with a small quantity of water to form an oily liquid heavier than water ; it is slightly soluble in water, and smells like creosote.

The following colouring-matters have been prepared from phenol : *Picric acid.* Strong nitric acid converts phenol and cresol into trinitrophenol (or picric acid) and trinitrocresol respectively ($C_6H_6O + 3HNO_3 = C_6H_3(NO_2)_3O + 3H_2O$). Picric acid is a bright yellow crystalline substance, and is used for dyeing wool and silk. The picrates, such as picrate of potash, $C_6H_2K(NO_2)_3O$, are very explosive substances. When picric acid is heated with cyanide of potassium, a purple-brown substance (*isopurpurate of potash*) is formed, which is used as a brown dye.

When carbolic acid, oxalic acid, and sulphuric acid are heated together, a scarlet colouring-matter, *coralline* or *rosolic acid* ($C_{20}H_{16}O_3$), is produced.

Naphthaline ($C_{10}H_8$) is a crystalline solid obtained from oil of coal-tar. When treated with nitric acid it yields nitronaphthaline ($C_{10}H_7NO_2$), which can be converted by nascent hydrogen into naphthylamine ($C_{10}H_7NH_2$). These products correspond perfectly with benzol, nitrobenzol, and

aniline; and colouring-matters are prepared from naphthylamine precisely as rosaniline, &c. are prepared from aniline. Thus, Magdala red is $N_3 \left\{ \begin{matrix} (C_{10}H_6)_3 \\ H_3 \end{matrix} \right.$ and gives violet and blue products, when one, two, or three of the ammonia hydrogen atoms are replaced by ethyl, amyl, phenyl, &c.

Anthracene is a crystalline solid obtained from the least volatile part of the oil of coal-tar—that is, from the part which comes over at the very end of the distillation. It has the composition $C_{14}H_{10}$. By oxidation it is converted into *anthraquinone* ($C_{14}H_8O_2$), from which, by means of various reactions, which cannot be detailed here, two colouring-matters are obtained—namely, *alizarine* and *anthrapurpurine* ($C_{14}H_8O_4$ and $C_{14}H_8O_5$). The first of these is identical with the *alizarine*, and the second isomeric with the *purpurine* obtained from madder.

2. *Natural Colouring-matters.*—We shall describe first the colouring-matters obtained from plants.

Madder is the root of various species of *Rubia*, especially *Rubia tinctorum*, *Rubia cordifolia*, and *Rubia peregrina*. It is imported from Smyrna and Cyprus, and is also grown near Avignon, in Alsace, and in Holland. Madder contains, besides woody tissue, a bitter extractive matter, and sugar, two substances which give it its value as a dye-stuff; these are *ruberythric acid* ($C_{20}H_{22}O_{11}$) and *purpurine* ($C_{14}H_8O_5$). In the presence of the nitrogenous substances contained in the madder, *ruberythric acid* undergoes a kind of fermentation, by which it is converted into a kind of sugar, and *alizarine* ($C_{14}H_8O_4$). As dyes, the *alizarine* and *purpurine* themselves may be used, but more frequently preparations of madder containing them, and known as 'flowers of madder' and *garancine* (from *garance*, the French name for madder), are employed.

Flowers of madder consist simply of powdered madder, from which the soluble substances have been removed by the action of slightly acidulated water. The water removes the sugar originally present in the madder, and also that produced by the decomposition of the ruberythric acid, and leaves undissolved the woody tissue, the alizarine, and purpurine. The sweet solution thus obtained is sometimes allowed to ferment, and then distilled, thus yielding alcohol. The washed residue, pressed, dried, and again ground, amounts to one-half of the weight of the original madder; as it contains very nearly all the alizarine and purpurine, it is therefore nearly twice as powerful a dye-stuff, and besides, gives better colours, as the water has removed various yellow substances which affect the purity of the colour. *Garancine* is prepared by acting upon madder by means of sulphuric acid. The acid partially destroys the woody matter, and sets free colouring-matter, which in the madder itself is combined and inactive. Thus, 100 parts of madder yield 40 parts of garancine, and these 40 parts of garancine have the tinctorial value of 200 parts of madder. It is this gain of colouring-matter which renders it profitable to manufacture garancine, although the colours produced are not so pure as those obtained from the 'flowers.' We have mentioned above that part of the colouring-matter (about one-half) remains combined and inactive in the madder, and can be set free by the action of sulphuric acid. This may be done either at once, as in the manufacture of garancine; or, the woody residue, remaining in the dye-vats after the cloth has extracted all the colouring-matter that it can from the madder or flowers of madder, may be treated with sulphuric acid, and thus converted into what is called *garanceux*, an inferior kind of garancine.

Alizarine and purpurine unite with some metallic oxides or hydrated oxides, forming coloured insoluble compounds called 'lakes.' Thus, the compound of alizarine or purpurine with hydrate of alumina is red, that with hydrated ferric oxide is violet, or, when seen in mass, black. This character, which alizarine and purpurine share with many vegetable colouring-matters, is, as we shall see, of great importance in dyeing.

Indigo.—This very valuable blue colouring-matter is obtained from a considerable number of plants, belonging to different natural families. By far the most of the indigo of commerce is derived from plants belonging to the genus *Indigofera*—natural order, *Leguminosæ*. The most important are *Indigofera tinctoria*, *Indigofera disperma*, *Indigofera Anil*, and *Indigofera argentea*. These indigo plants are chiefly cultivated in Bengal, Java, China, Egypt, Mexico, and the West Indies. The colouring-matter is mainly derived from the leaves, so that those varieties which have most leaves and least wood are preferred.

In some localities, the leaves are pulled, but usually the entire plant is cut down. The following is a description of the manufacture of indigo in Bengal.

The factory contains filters, presses, a boiler, a drying-house, tanks for water, and from 30 to 40 vats. These vats are built of brick cemented in the inside. They are about 20 feet square, by two and a half to three feet in depth. They are arranged in two rows, one behind the other, and on a higher level, so that the contents of a vat of the upper row can be emptied by a tap into one of the lower row. The plants cut in the morning are packed before evening in the upper row of vats. When the vats are well packed with plants, water is run into them, so as to cover the plants. Fermentation then sets in, and lasts from 9 to 14 hours. When this is completed, the liquid, now more or less bright yellow in colour, is allowed to run into the lower vats. It is then thoroughly stirred by naked workmen with long bamboo canes. During this agitation, which is continued for two or three hours, the liquid becomes green, and the indigo collects in flocculent particles. It is allowed to settle, and the clear brown liquid is run off by opening holes at different levels in the vat. The precipitate is then boiled in a copper vessel, in order to prevent a second fermentation, which would injure the quality of the product; it is left to settle for twenty hours, and again boiled for two or three hours. It is then run into a large filter, consisting of a vat, over which are placed bamboos covered with rushes, and over all a stout linen cloth. Most of the indigo remains on the cloth, and what runs through with the liquid settles in the vat, and is recovered. The indigo collected on the cloth is pressed into wooden moulds. The bricks so formed are carefully dried in the drying-house, which is protected from the direct rays of the sun.

The *rationale* of this process will be understood

when the chemical nature of indigo, and the form in which it occurs in the plant, have been explained. Indigo does not exist as such in the plant. The indigo plants contain a substance called *indican*, which undergoes fermentation, yielding *indigo blue*, and a kind of sugar called *indiglucine*. This decomposition is therefore analogous to that by which *alizarine* is obtained from *ruberythric acid* (p. 342); indeed, we may remark in passing, that there are in many plants substances called *glucosides*, which, when fermented—and many of them when boiled with acids—yield a kind of sugar and another substance. Thus, *amygdaline*, contained in the bitter almond, yields sugar, and prussic acid, and benzoic aldehyd; *myronic acid*, contained in the black mustard-seed, yields sugar and essential oil of mustard. Many other instances might be given.

Indigo blue has the composition C_8H_5NO. It has a deep blue colour, and when rubbed with a smooth surface, a copper-coloured metallic lustre. It can be volatilised unchanged, when very cautiously heated in small quantities. It is quite insoluble in water, alcohol, ether, oils, and in dilute acids and alkalies.

When treated with reducing agents in alkaline solutions, it takes up hydrogen, and is converted into a colourless substance, which dissolves in the alkali. This colourless substance can be precipitated from such solutions by neutralising them with an acid. It is called indigo white, and has the composition $C_{16}H_{12}N_2O_2 = 2C_8H_5NO + H_2$. When indigo white, or its alkaline solution, is exposed to the air, the oxygen rapidly takes hydrogen from it, and indigo blue is produced. Now, in the fermenting vat, ammonia and formic acid are produced—that is, an alkali and a reducing agent; the indigo blue, therefore, formed by the fermentation of the indican, is converted into indigo white, which dissolves in the alkaline liquid. This is the yellow solution which flows from the fermenting to the beating vat. In the beating vat it is brought into thorough contact with the oxygen of the air, and oxidised to indigo blue:

$$\underset{\text{Indigo White.}}{C_{16}H_{12}N_2O_2} + O = \underset{\text{Indigo Blue.}}{2C_8H_5NO} + H_2O.$$

We shall see that this conversion of indigo blue into soluble indigo white, and the reoxidation of the latter into insoluble indigo blue, is of the greatest importance in dyeing.

Action of Sulphuric Acid on Indigo Blue.—By the action of strong, or, most conveniently, fuming, sulphuric acid (p. 337) on indigo blue two acids are formed: 1. Sulphophenicic acid ($C_{16}H_{10}N_2SO_5 = 2C_8H_5NO + SO_3$), and 2. Sulphindigotic acid ($C_8H_5NSO_4 = C_8H_5NO + SO_3$); the latter is always formed if the sulphuric acid is strong and the action prolonged. The solutions of these acids are deep blue. Their salts with alkalies, such as sulphophenicate of soda ($C_{16}H_9NaN_2SO_5$) and sulphindigotate of soda ($C_8H_4NaNSO_4$), are soluble in water. A variable mixture of the two salts just named is sold under the names *indigo carmine* and *ceruleine*. It is prepared by taking advantage of the fact, that sulphophenicates and sulphindigotates of the alkalies, although soluble in water, are insoluble in solutions of most salts. The solution of indigo in sulphuric acid, which always contains a large excess of sulphuric acid, is neutralised with carbonate of soda. Sulphophenicate and sulphindigotate of soda are formed, and also sulphate of soda: the presence of this in the solution renders the two former salts insoluble; they are accordingly precipitated, and can be collected on a filter. Indigo carmine usually consists chiefly or entirely of *sulphindigotate of soda*.

We have now considered in some detail the two most important of the natural vegetable dye-stuffs, madder and indigo; the others need not occupy us long.

Logwood is the wood of the tree *Hæmatoxylon campechianum*, belonging to the natural order Leguminosæ. The tree grows in Central America and the West Indies. The colouring power of the wood depends on a substance called *hæmatoxyline*, having the composition $C_{16}H_{14}O_6$. This substance occurs in the wood, partly free, partly as a 'glucoside' (see above). The glucoside is decomposed by fermentation of the wet powder. Hæmatoxyline is a colourless or faintly yellow crystalline substance. With acids it forms a yellow solution, which, on the addition of an alkali, changes to red. It acts as a weak acid, forming salts with strong bases. These salts are very readily oxidised, and although themselves colourless, become blue or black by absorbing oxygen. Thus, with alumina, we obtain a violet blue; with oxide of iron, a bluish black; with oxide of zinc, a purple; with stannous oxide, a violet; bichromate of potash is at once reduced, oxidising the hæmatoxyline, and producing a deep violet black compound. It is used for dyeing blue and black, advantage being taken of the above-mentioned reactions.

Brazil wood is obtained from various trees belonging to the natural order Leguminosæ. Thus, we have *Pernambuco wood* from *Cæsalpinia crista; Brazil wood* proper from *Cæsalpinia braziliensis; Nicaragua wood* from *Cæsalpinia echinatos; Sapan wood* from *Cæsalpinia Sapan; Bresillet wood* from *Cæsalpinia vesicaria*. We do not as yet know certainly what is the colouring principle of these woods, or whether there is only one or more such principles; at all events, all of these woods act in very nearly the same way. The colouring principle exists in the wood as a glucoside. It is itself colourless, but absorbs oxygen, and becomes red. It combines with metallic oxides, forming 'lakes.'

Sandal-wood is the wood of the *Pterocarpus santalinus*, a beautiful tree, growing in Ceylon and the Coromandel Coast. Its colouring principle, called santalin, is of a red colour.

Fustic.—What is called 'old fustic' is the wood of the *Morus tinctoria*, a tree which grows in the East Indies, in South America, and West Indies. It contains two colouring-matters, *Morin* and *Maclurin*, having the composition respectively $C_{12}H_8O_6$ and $C_{13}H_{10}O_6$. The wood is used for dyeing yellow. 'Young fustic,' 'bois de fustet,' is the wood of the *Rhus cotinus*, growing in the West Indies, the Levant, Spain, Italy, Hungary, the Tyrol, and the south of France. Its colouring principle has been named 'fustine,' and appears to be identical with 'quercetine.' It is used for dyeing yellow.

Quercitron is the bark of the *Quercus tinctoria*, a kind of oak growing in Pennsylvania, North and South Carolina, and Georgia. It contains a crystalline substance, 'quercitrine,' which, when

boiled with acids, yields a sweet substance, and a colouring principle called 'quercetine.' It is used as a yellow dye.

Persian or Turkey Berries.—The fruit of various species of *Rhamnus.* They are used for dyeing morocco leather and wool yellow. The *Rhamnus catharticus* yields the pigment called 'sap green.'

Turmeric—the root of *Curcuma longa* and *Curcuma rotunda*—is used for dyeing silk and wool yellow. Its colouring-matter is curcumin ($C_8H_{10}O_2$). Paper stained yellow with turmeric is used as a test for alkalies and for boracic acid, by which it is rendered brown.

Annatto or *Arnotto*, a yellowish-red colouring-matter, prepared from the fruit of *Bixa orellana.* It is used as an ingredient in varnishes, for dyeing silk, and for colouring cheese and butter.

Weld is the dried plant *Reseda luteola*, a plant belonging to the same genus as mignonette. The colouring-matter is called *luteoline.* It is used as a yellow dye.

Safflower consists of the dried petals of *Carthamus tinctorius*, a thistle-like plant cultivated in the Levant, Egypt, India, Southern Russia, Central Germany, Hungary, Italy, Spain, and South America. It contains two colouring-matters—one yellow, soluble in water, which is not used as a dye; the other red, insoluble in water, but soluble in alkalies. This red colouring-matter is called *carthamine*, and has the composition $C_{14}H_{16}O_7$. Safflower is used for dyeing silk red. Carthamine, mixed with French chalk, constitutes the *rouge* used as a face-powder.

Orchil and *Cudbear.*—These are red dye-stuffs prepared from various lichens. The colouring-matter is *orceine* ($C_7H_7NO_2$). The blue colouring-matter 'litmus' is obtained from the same lichens. Its colouring principle is called *azolitmine*, and appears to have the composition $C_7H_7NO_4$. Paper stained with litmus is used as a test for acids, which change the colour to red; and reddened litmus-paper is used as a test for alkalies, which restore the blue colour.

PIGMENTS AND DYE-STUFFS OF ANIMAL ORIGIN.

Of these, the most important are *Cochineal*, *Lac*, and *Purree.*

Cochineal.—True cochineal consists of the bodies of the female *Coccus cacti*, an insect found on various species of cactus in Mexico, Spain, the Canary Islands, Algeria, and Java. The insects are collected after they have laid their eggs, and are killed by being subjected to the action of steam, or by the heat of an oven. *Carmine* is the colouring-matter prepared from cochineal by various processes, kept secret by the makers. It owes its beautiful red colour to carminic acid ($C_{14}H_{14}O_8$), a red solid, soluble in water and alcohol. Carminic acid appears to be a glucoside, and yields, when boiled with dilute sulphuric acid, a special kind of sugar, and a substance called *carmine-red.*

Lac is the product of an insect, *Coccus laccæ*, a native of India and the East Indian Islands. The female insect punctures the twigs of various trees and shrubs, and lays her eggs in the milky juice which exudes. This juice hardens into a resinous mass, which incloses the eggs and the dead bodies of the parent insects. The caterpillar, emerging from the egg, eats its way through the surrounding resin. Lac occurs in commerce in three forms: 1. Stick-lac—that is, lac in its natural state, adhering to the twigs from which it was formed; 2. Seed-lac—that is, lac picked off from the twigs, and deprived by treatment with water of some of its colouring-matter; and 3. Shell-lac—that is, lac which has been fused and strained through a cloth, and has thus lost nearly all its colouring-matter, and consists almost entirely of lac-resin. Shell-lac is used for the manufacture of sealing-wax; dissolved in alcohol, it forms the common spirit-varnish. Lac-dye is obtained from stick-lac, which contains about 10 per cent. of colouring-matter. It is probably produced by the insect, as it bears a close resemblance to cochineal, the product of the *Coccus cacti.*

Purree is a substance the origin of which is unknown. It is imported from India and China in rounded masses of 3 or 4 oz. weight, and is used for making the pigment *Indian yellow.* It is generally believed to be of animal origin, and to be derived from the urine of camels and elephants. The colour is due to the *euxanthate of magnesia. Euxanthic acid* has the composition $C_{21}H_{18}O_{11}$.

PAINTS consist of colouring-matters mixed with a 'vehicle'—that is, a liquid which hardens or dries on exposure. Paints are divided into water-colours and oil-colours. In the former, the vehicle is an aqueous solution of gum, and the drying is caused by the *evaporation* of the water; in the latter, the vehicle is boiled linseed-oil, and the drying or hardening is caused by the *oxidation* of the oil (see CHEMISTRY).

DYEING AND CALICO-PRINTING.

In order to produce a fast colour upon a fabric made of animal or vegetable fibre (wool, silk, cotton, or linen), it is necessary—1. That the colouring-matter, or the materials for producing it, should be presented to the fibre in the liquid state, so that it may soak into the fibre; 2. That when it has soaked into the fibre it should be rendered insoluble, so as to prevent its being washed out. There are various ways in which an insoluble colour can be produced from solutions of soluble substances—1. The solvent may be removed; 2. The colouring-matter may form an insoluble compound with the substance of the fibre; 3. Two substances may be separately presented in solution to the fibre, and these two substances may, by acting upon one another, produce an insoluble colour; 4. A soluble substance may, after its introduction into the fibre, be changed into an insoluble colour by the action of the oxygen of the air.

We shall give some instances of these different ways of rendering the colouring-matter insoluble.

1. Removal of the solvent.—This method is of very limited applicability. It is obvious that the mere evaporation of *water* in which the pigment is dissolved is not a case in point, for that would leave the pigment ready to be washed out again. As an instance of a case in which this method is applicable, we may take the dyeing of cloth with an ammoniacal solution of a salt of copper. When the cloth soaked in such a solution is exposed to the air, the ammonia evaporates, and

leaves an insoluble basic salt of copper in the fibres of the cloth.

2. The formation of an insoluble compound of the colouring-matter with the substance of the fibre.—This method applies only to the animal fibres (silk and wool) which are capable of forming stable, insoluble compounds with some colouring-matters, such as picric acid and the aniline colours.

3. The action of two solutions successively introduced to the fibre.—This is by far the most important method of dyeing, and may be conveniently considered under two heads: (*a.*) Where a chemical decomposition or a double decomposition takes place; and (*b.*) where the substance first introduced (in this case called the *mordant*) becomes insoluble in the fibre, or is decomposed there, producing an insoluble substance; and then the dye-stuff, into a solution of which the fabric is dipped, enters into combination with this insoluble substance derived from the mordant. We shall give a few examples of each of these.

(*a.*) *Carthamine*, the colouring-matter of safflower, is soluble in alkalies; cloth dipped in such a solution is stained or coloured red by it, and the colour can be easily washed out; but if, after being dipped in the alkaline solution of carthamine, the cloth is treated with an acid, the alkali is neutralised, and the carthamine precipitated in the fibres. Cotton is dyed yellow by dipping it, first, in a solution of acetate or nitrate of lead, and then passing it through a solution of chromate of potash. Here double decomposition takes place in the fibres—acetate or nitrate of potash and insoluble yellow chromate of lead (chrome yellow) being produced. Prussian blue is dyed in a similar way; the fabric being treated successively with solutions of ferric chloride or acetate, and ferrocyanide of potassium, acetate of potash or chloride of potassium, and insoluble ferric ferrocyanide (Prussian blue), are formed. One of the methods employed in dyeing silk black may be taken as another instance. The silk is dipped in a solution of tannin, which combines loosely with the substance of the silk, and then in a solution of a ferric salt. The black compound of ferric oxide and tannin, which is the basis of common black ink, is thus formed.

(*b.*) When a fabric is dyed by successively dipping it into two liquids, the first is usually called the *mordant*. We shall, however, here restrict this term to substances which are introduced in a state of solution into the fibre; there become insoluble, or give rise, by decomposition, to an insoluble body, which unites with the colouring-matter when the fabric is dipped in the dye-vat.

The chief substances used as mordants are—salts of alumina, ferric and ferrous salts, stannous chloride, stannic chloride, stannate of soda, albumen from eggs or from blood, and gluten of wheat. We shall shortly consider the mode of action of these substances. The soluble salts of alumina, especially the acetate, have a tendency to form basic salts. Thus, if a solution of acetate of alumina is boiled, an insoluble basic acetate is precipitated. Under some circumstances, the solution may even lose the whole of its acetic acid, leaving hydrate of alumina. Similarly, when a mixed solution of sulphate of alumina and acetate of alumina is boiled, acetic acid separates, and insoluble basic sulphate of alumina is precipitated. Now, when cloth is steeped in such solutions, and then heated, or even exposed for some time to the air, the change just described takes place; acetic acid is given off, and an insoluble basic salt of alumina—or the hydrate of alumina itself—is left deposited in the fibres. Ferric salts act in exactly the same way, insoluble basic salts, or even ferric hydrate, being produced. 'Tin salt' (stannous chloride with water of crystallisation, $SnCl_2,2HCl$) is a crystalline, colourless solid, formed by the action of aqueous hydrochloric acid on metallic tin. It dissolves in water, but a dilute solution undergoes a change, oxychloride ($SnCl_2,SnO,2H_2O$) being precipitated as an amorphous white powder, and hydrochloric acid remaining in solution. In the cloth, this change also takes place, and the insoluble oxychloride, partially oxidised to hydrated stannic oxide (SnO_2,H_2O), remains in the fibre. Stannic chloride (called by the dyers 'physic') has the composition $SnCl_4$ when pure; as used for dyeing, it generally contains some stannous chloride. It dissolves in water; but when the solution is diluted, hydrated stannic oxide is precipitated, and hydrochloric acid left in solution. 'Pink salt' is a compound of stannic chloride and chloride of ammonium ($SnCl_4,2NH_4Cl$); its dilute solution undergoes, when heated, the same change as has been just described in the case of stannic chloride. As stannic oxide is a very feeble acid, its compounds with bases, such as stannate of soda (Na_2O,SnO_2), are easily decomposed. If a piece of cloth, dipped in a solution of stannate of soda ('preparing salt'), be exposed to the air, the atmospheric carbonic acid is sufficient to precipitate stannic hydrate (H_2O,SnO_2).

We see, then, that all these metallic salts, when used as mordants, deposit in and on the fibre insoluble substances, which are either basic salts or hydrated oxides. It has already been mentioned that many natural colouring-matters form insoluble compounds, called 'lakes,' with metallic oxides. When, then, the mordanted cloth is dipped in a solution of a dye-stuff of this kind, an insoluble lake is produced wherever the basic salt or hydrated oxide has been deposited. The colour of the lake depends both upon the mordant and upon the dye-stuff. Alumina and tin mordants give colours resembling those of the colouring-matter itself, but iron mordants, as a rule, change the colour. Thus, madder gives a red with an alumina mordant; but with iron, a black, if the mordant is used in strong solution; and a violet, if dilute. Wool mordanted with alumina is dyed blue by indigo carmine (p. 343), sulphindigotate of alumina being formed.

Albumen and gluten are used as mordants when cotton has to be dyed with aniline colours. It has already been stated that silk and wool absorb these colours without the intervention of a mordant; and by surrounding the vegetable fibre with a thin layer of a substance resembling in some respects the substance of silk or wool, cotton can be made to do so likewise. This treatment of cotton or linen with albumen or gluten is sometimes called 'animalisation,' because the vegetable fibres are thus made to resemble animal fibres in their power of taking up colours. As tannin forms insoluble coloured compounds with the aniline colours, cotton is sometimes dyed by dipping it, first, in a solution of tannin, and then in a solution of the aniline colour.

4. Formation of insoluble colouring-matter by oxidation of a soluble substance.—The most important instance of this method is indigo dyeing. It has already been stated (see p. 343) that indigo blue (C_8H_5NO) is converted into indigo white ($C_{16}H_{12}N_2O_2$), when treated with a reducing agent and an alkali, and that the indigo white thus produced dissolves in the alkaline solution. Further, we have seen that when this solution of indigo white is exposed to the air, indigo blue is reproduced by oxidation. When cloth or yarn is soaked in an alkaline solution of indigo white, and then exposed to the air, the same change takes place, and the insoluble indigo blue is deposited in the fibres.

The various processes of indigo dyeing differ from one another chiefly in the reducing agent employed. Thus, we have the 'copperas vat,' in which lime and potash are used to render the solution alkaline, and copperas (ferrous sulphate) is the reducing agent. The ferrous sulphate is at once decomposed by the powerful bases, lime and potash, and ferrous hydrate precipitated. This gradually becomes oxidised to ferric hydrate, taking oxygen from the water; while the hydrogen unites with the indigo blue, and forms indigo white. This vat is usually employed in dyeing cotton. In the vats used for dyeing wool, a process of reduction resembling that by which indigo white is prepared in the manufacture of indigo, is used. Potash or soda is used as the alkali, and the indigo is reduced by the fermentation of bran, molasses, or a plant called 'woad,' which itself contains a small quantity of *indican*.

The production of brown colours by means of tannin is also a case of oxidation, the tannin, especially in the presence of alkalies, being converted into a brownish-red substance. Also black peroxide of manganese (MnO_2) is produced by oxidation of manganous hydrate (MnO,H_2O) deposited in the fibre by the action of an alkali upon a soluble manganous salt.

Calico-printing is merely a special case of dyeing in which the action is restricted to parts of the cloth, so as to produce a pattern.

This may be accomplished in various ways. We shall describe four of these ways, observing that sometimes two of them are used at once.

1. A mordant may be applied, in the form of the pattern, to the cloth by means of blocks or cylinders, so that the mordant, thickened with starch or gum, is fixed upon those parts of the cloth which are intended to be coloured. The cloth is then passed through the dye-vat, the dye-stuff fixes itself upon the mordanted pattern, and can be washed out of the rest of the cloth. By this method, several different colours can be produced by one operation. Thus, if we print by means of four blocks or cylinders, four patterns, *a*, with alumina mordant; *b*, with weak iron mordant; *c*, with strong iron mordant; *d*, with a mixture of alumina and iron mordant; and then dye in a madder vat—the pattern *a* comes out red; *b*, violet; *c*, black; and *d*, chocolate; while the unprinted parts are white.

2. The cloth may be printed with what are called resists—that is, substances which will prevent the dyeing taking effect upon the parts of the cloth covered by them. We thus obtain a white pattern upon a coloured ground, the whole of the cloth except the parts covered by the 'resist' being dyed. Resists are most frequently used in indigo dyeing, and then consist of substances, such as cupric salts, which can oxidise white to blue indigo. When the cloth upon which such a composition has been printed is dipped in the indigo vat, the solution of indigo white soaks into all parts of the cloth except the printed pattern, into which it cannot penetrate, the indigo white being converted by the resist into insoluble indigo blue. On taking the piece of cloth out of the vat, the pattern is seen to be covered with indigo blue, but not dyed; the blue is superficial, and can be washed off. Along with the resist, a mordant for another colour may be printed; thus, alumina mordant mixed with the resist will be ready to receive a red colour from a madder bath, after the ground has been dyed blue in the indigo vat.

3. A method of producing a white pattern on a coloured ground by 'discharging' the colour from the pattern has already (p. 339) been described; we shall here mention one or two other processes of a similar kind. A piece of cloth uniformly mordanted may have a pattern printed on it in a substance which renders the mordant inoperative. Thus, if an alumina or iron mordant is used, we can print a pattern upon the cloth with a mixture containing a fixed acid, such as citric acid. This prevents the formation of a basic salt or hydrated oxide, upon which, as already described, the action of the mordant depends—the pattern, therefore, is not dyed when the cloth is passed through the dye-vat.

If the acid mixture is printed *before* the cloth is mordanted, the same result is produced, and the process becomes one of 'resist' rather than discharge. Special discharges are used with some colours. Thus, indigo can be discharged by certain oxidising agents which convert it into isatine ($C_8H_5NO_2$), a soluble substance which can be washed away. Prussian blue can be discharged by caustic potash, which converts it into soluble ferrocyanide of potassium, which is washed out with water, and hydrated ferric oxide, which can be removed by means of dilute sulphuric acid.

4. The colouring-matter itself, mixed with thickening material and mordant, may be printed on the cloth, and then, by the action of steam, fixed to the fibre. The thickening material (starch or gum) is then washed away. Colours produced in this way are not so fast as those regularly *dyed*, but even in this case a certain amount of fixing *in* the fibre takes place, probably by the mordant and dye-stuff finding their way uncombined into the fibre, and uniting there.

In conclusion, we may mention two processes by which patterns are produced upon cloth, which do not fall under any of the above divisions. These are 'China-blue' printing, and what is called the 'Scottish press' process.

In China-blue printing (so called from the resemblance of the colour to that of blue porcelain or 'china'), finely powdered indigo blue, mixed with reducing agents, and starch or gum, is printed on the cloth, which is then passed through an alkaline bath. The indigo is thus reduced to indigo white, which soaks into the pattern, but does not spread beyond it, being retained by the gum. By exposure to the air, the indigo white is reoxidised to indigo blue. In the Scottish press process, the cloth is folded up and placed in a powerful press between metal plates with holes

corresponding to the pattern. Mordants and dye-stuffs are then successively forced through, and act only on the parts opposite the holes.

LEATHER

consists of the skin of mammals so prepared that it is not stiff and brittle when dry, and when wet does not easily putrefy. There are three different methods of making leather—namely, Tanning, Tawing, and Shamoying; and there are thus three essentially different kinds of leather—tanned leather, white leather, and shamoy, or wash leather.

The skins undergo a preliminary treatment, which is of nearly the same character for all the three processes. This consists in cleaning the skin, freeing it from hair, epidermis, blood, fat, portions of flesh, &c. by soaking in water, scraping, and paring. The hair is loosened in some cases by treatment with lime; as it is difficult to remove the lime entirely from very thick skins, these are allowed to undergo a slight superficial decomposition, after which the hair and epidermis are easily scraped off. Very thin skins are liable to be injured by either of these processes, and from them the hair is removed by the application of a substance called 'rusma,' which is a mixture of nine parts of lime and one of orpiment, which very rapidly loosens the hair. The skins, after being cleaned, are subjected to the process called 'swelling.' This consists in placing the hides in a tank containing water and bran. The bran undergoes fermentation, producing acetic and lactic acids; these remove any lime which may have been left; while, by absorbing water, the skins are rendered soft. The skins are now ready to be tanned, tawed, or shamoyed.

Tanning.—This consists in the absorption by the skin of *tannin*, a substance mentioned in the paper on CHEMISTRY, but which we must now describe somewhat more fully.

Tannin is a generic name given to a considerable number of substances of vegetable origin. They all give a dark colour, either blue-black or olive-green, with ferric salts; are easily oxidised, especially in the presence of an alkali, forming dark-coloured substances: all combine with the fibrous tissue of skin to form leather, and all unite with gelatine to form an insoluble substance. It has been supposed that this insoluble gelatine compound is the same substance as leather, but this is certainly not the case; skin contains no gelatine, although, by prolonged boiling, the fibrous tissue of the skin can be converted into gelatine. The most important sources of tannin for tanning purposes are *oak-bark; sumach*, the bark of plants belonging to the genus *Rhus; catechu*, an extract prepared from various plants; *dividivi*, from *Cæsalpinia coriaria; valonia*, the cups of the acorns of *Quercus ægilops; nut-galls*, excrescences produced by insects on the leaves and leaf-stalks of *Quercus infectoria*.

The prepared skins are tanned in two different ways—tanning in the bark, and tanning in the liquor. Tanning in the bark is carried on in pits lined with oak-wood. A layer of spent-tan is placed at the bottom, then an inch of fresh tan (oak-bark sometimes mixed with valonia flour), then a hide, then another layer of bark an inch thick, then another hide, and so on. All cavities are filled up with bark, and a layer about a foot deep of spent-tan is placed on the top. Water is then introduced till it stands a little above the uppermost hide. The hides remain in this pit undisturbed for about eight or ten weeks, if pure oak-bark is used; if valonia has been added, a shorter time is required. The hides must be taken out of the pit before all the tannin has been absorbed from the liquid, and before too much acetic acid has been formed by fermentation, and placed in a second pit, those hides which were formerly at the top being put at the bottom. Here the same arrangement of hides and tan is made as in the first pit, only rather less tan is used. In this pit the hides remain for three or four months, and then in a third similarly arranged pit for four or five months. Very thick hides sometimes require a fourth, or even a fifth treatment, occupying altogether two years or more. The thicker the hide the longer is the time required to tan it. Thus, the skins of cows are tanned in about a year; those of calves, in four or six months.

Perfectly tanned leather is recognised by examining a section made with a knife; the surface should be uniform in character, without fleshy or horny streaks.

The second mode of tanning is tanning in liquor, or quick-tanning. It is used for all except thick hides intended for sole leather, which are tanned in the bark.

The liquor is a cold infusion of oak-bark or other material yielding tannin. The hides are first placed in very dilute liquor, in order that there may be no superficial tanning, which would render it difficult for the liquor to penetrate into the interior of the skin. They are moved about in the tank to bring new solution in contact with them, and when they are taken out, they are pressed and rolled, to remove the spent liquor, and enable them more easily to absorb new. The hides are moved into successively stronger liquors, remaining eight hours in the first or weakest, sixteen in the second, twenty-four in the third, forty-eight in the fourth, and in the last and strongest until the tanning is completed. Leather tanned in this way is often placed between layers of bark in the pit for a few weeks, to make it denser. In this way calves' skins can be tanned in eight days; thicker skins require considerably longer, four or five weeks being sometimes necessary. Various plans have been suggested for hastening the tanning process, such as forcing the liquor through the skins under pressure, passing them between rollers in the liquor, &c.; but none of these has been extensively adopted.

After the leather is fully tanned, it is 'curried,' or prepared for use. The currying varies very much with the different kinds of leather and purposes to which it is to be applied. It consists essentially of smoothing the leather by paring, scraping, and rubbing, and of rendering it supple by rubbing into it oil and tallow, or the mixture of fatty acids and soap which occurs as a waste product in the process of 'shamoying.'

Russia leather is tanned in the usual way, and then rubbed on the flesh-side with birch-tar, and dried and washed on the hair-side with solution of alum. It is then rolled in various directions with a grooved roller, which gives it the peculiar surface-marking, stained with infusion of Pernambuco wood, hammered and rolled, and finally oiled and rubbed with flannel.

Cordovan leather resembles *morocco*, but differs from it in that, in the latter, the grain is produced artificially by means of rollers, while in the former the natural grain is preserved. It is tanned with sumach and dyed.

Tawing.—This method of making leather is chiefly applied to the skins of sheep, goats, and calves, although sometimes the skins of horses and cows are tawed.

The process consists in treating the hides, prepared as for tanning, with a solution of alum and common salt. In this solution they lie for an hour; they are then taken out and piled upon one another wet. In this condition they remain for two or three days; they are then wrung out and hung on laths to dry. When dry, they are again uniformly moistened, and rubbed with a convex iron, to give pliancy and remove folds.

Hungarian tawing is a variety of the process, chiefly differing from that above described in that larger and thicker skins are used; the preliminary treatment is shorter and simpler, the alum and salt solution stronger, and the skins are moved about in the liquor, in which they remain for eight days. Often the Hungarian leather contains no tallow or oil; but sometimes it is warmed, rubbed with tallow, and then held over a charcoal fire, to make the tallow soak better into it, and then cooled in the air.

Whiteglove leather is prepared by tawing from the skins of lambs and kids. After undergoing the usual tawing process, they are placed in a second bath, which contains for 100 skins 9 lbs. of wheat-flour, the yolks of 50 eggs, 2½ lbs. of alum, 1 lb. common salt, and a gallon and a half of water. Sometimes, instead of the yolks of eggs, fine olive-oil is used. In this they are left some days, then dried, rolled, pressed, and polished on the grain side.

Shamoying.—For this process the skins are prepared in the same way as for tanning or tawing. They are then sprinkled with fish-oil, rolled up into balls, and hammered with heavy falling hammers for two or three hours. During this time they are occasionally taken out, again oiled, and put back under the hammer. When they have taken up enough oil, they are taken out, and either hung up in a warm place or piled up in heaps, where they become warm by the oxidation of the oil. They are next steeped in a very weak lukewarm solution of potash, which saponifies the excess of the oil. The skins are lastly wrung out, dried, and rubbed. From the solution of soap just mentioned, a mixture of fatty acid and soap separates; this is called 'dégras,' and is used, as already mentioned, for oiling tanned skins.

Parchment and Vellum are not, strictly speaking, *leather;* they have undergone no chemical change, but are merely thoroughly cleaned and dried skins.

FATS AND FATTY OILS.

These are substances occurring in animals and vegetables. They are either liquid at ordinary temperatures (oils) or fusible solids (fats). They are insoluble in water, but very readily soluble in ether and in bisulphide of carbon. They cannot be distilled without decomposition. When treated with solutions of fixed caustic alkalies (caustic potash or caustic soda), they are *saponified*—that is, they are dissolved, and the solution contains a *soap* and glycerine. They are *greasy* to the touch, and leave a *permanent* greasy spot on paper. The chemical constitution of the fats and fatty oils is explained in the paper on CHEMISTRY. We shall here describe the ways in which they are obtained, and the methods used for purifying them.

VEGETABLE OILS.—These are almost entirely obtained from the *seeds* of many kinds of plants. The seeds are first ground to a meal, and this is warmed and strongly pressed in coarse hair-cloths between metal plates by means of a hydraulic press. The greater part of the oil flows out, leaving what is called the 'oil-cake.' The extraction of the oil may be, and to some extent in practice is, effected by means of bisulphide of carbon, in which oils are very readily soluble.

The vegetable oils may be divided into the Drying Oils and the Non-drying Oils. The former absorb oxygen when exposed to the air, and are converted into a dry 'varnish;' hence they are used for preparing oil-colours. The non-drying oils, when perfectly pure, are not altered by exposure to air;* but in the state in which they usually occur, mixed with small quantities of foreign matter, from the vegetable or animal tissue from which they are obtained, they become 'rancid'—that is, acquire a disagreeable taste and smell, and become acid to test-paper. By shaking a rancid oil with boiling water, and then in the cold with a weak alkaline solution, the fatty acids, on the presence of which the rancidity depends, are removed.

The most important DRYING OIL is Linseed-oil, obtained from the seeds of the common flax (*Linum usitatissimum*). Heated with *oxide of lead*, it dissolves about 5 per cent. of the oxide, and its *drying* character is greatly increased. When kept for a long time at a high temperature in contact with air, it is converted into a thick, rapidly drying varnish, much used for making printers' ink.

The other best known drying oils are: Oil of hempseed, from the seeds of the hemp plant (*Cannabis sativa*); poppyseed-oil, from the seeds of the opium poppy (*Papaver somniferum*), used chiefly as a salad-oil; walnut-oil, from the walnut, fruit of *Juglans regia*, also used as a salad-oil. *Croton-oil* and *castor-oil*, from the seeds of *Croton Tiglium* and *Ricinus communis*, can scarcely be classed among the drying oils, although in thin layers they slowly dry to a tough semi-solid substance. They are both used as purgatives; croton-oil being an exceedingly powerful purgative, castor-oil a mild and gentle laxative.

The NON-DRYING OILS consist mainly of *olein* and *palmitin;* some of them also contain *stearin* (see CHEMISTRY). Olein is an oily liquid; palmitin and stearin are fusible solids; the former melting at a lower temperature than the latter. Oils containing palmitin and stearin, when cooled to a low temperature, deposit these bodies in the solid form; when warmed again, the deposit dissolves in the olein. This may be easily observed in olive-oil, which, in cold weather, deposits a

* The non-drying oils, when exposed to the air in very thin layers (as, for instance, when rags or cotton-waste, used for wiping up oil, are exposed to air), are oxidised, and during this oxidation, heat is given out to such an extent that it has happened that a pile of rags soaked in oil has actually taken fire. Care should therefore be taken that such oily materials are not allowed to accumulate.

white substance, a mixture of palmitin and stearin. The most important vegetable non-drying oils are: Olive-oil, from the fruit of the olive (*Olea Europæa*). Almond-oil, from the fruit of *Amygdalus communis*, is obtained by pressure both from the sweet and from the bitter almond, and must be carefully distinguished from the 'oil of bitter almonds,' an entirely different substance (see CHEMISTRY); it consists of almost pure olein. Rape-oil, or colza-oil, from the seeds of *Brassica campestris:* this oil contains very little palmitin or stearin; it is chiefly used for burning, and is purified by the action of a little strong sulphuric acid, which chars the impurities, mainly fragments of vegetable tissue. Mustard-oil (not to be confounded with the *volatile oil of mustard*, see CHEMISTRY) is obtained by pressure both from the white and from the black mustard (*Sinapis alba et nigra*); it is a rather thick yellow oil. Palm-oil, from the fruit of *Avoira Elais* or *Elais Guianensis*, is a yellow *fat*, fusing at about 80° F. and therefore usually solid in this country: it consists almost entirely of a mixture of olein and palmitin. To remove the yellow colour, it is first melted over water, the solid impurities (fragments of the husk of the fruit) allowed to settle, and then the clear oil heated nearly to its boiling-point in a current of air. Coco-nut butter is obtained from the coco-nut, the fruit of *Cocos nucifera*, *Cocos butyracea*, &c.: it is white and soft, fuses at about 68° F. and consists of olein, palmitin, and the glycerides of *lauric acid* ($C_{12}H_{24}O_2$) and of an acid named *cocinic acid*, the composition of which has not been exactly ascertained.

The ANIMAL FATS AND OILS resemble in constitution and general character the non-drying vegetable oils. They consist almost entirely of mixtures of olein, palmitin, and stearin; the oils and more fusible fats containing most olein, the harder fats most stearin. The most important are: *Oils.*—Neatsfoot-oil, much used by watchmakers, is prepared by placing the bones of the feet of oxen, carefully cleaned from the hoofs and from adhering fat and skin, and well broken up, in a gently warmed oven, when the oil flows out, and is purified by allowing the impurities to settle in a closed glass vessel. It remains solid at the freezing-point of water, and does not readily become rancid. Fish-oil, or train-oil, is obtained from various large sea-animals—whales, seals, dogfish. It consists chiefly of olein and palmitin with some stearin. It is used as a lubricant, and for smearing leather (see p. 347), also (as indeed are all the cheaper oils and fats) for making soap. Cod-liver oil is obtained from the liver of the common cod (*Gadus morrhua*) and the ling (*Gadus molva*), also from the dorse (*Gadus callarius*) and coal-fish (*Gadus carbonarius.*) It is distinguished as 'brown,' 'pale,' and 'yellow' oil, according to its colour, which varies according to the mode of extraction. It consists chiefly of olein, palmitin, and stearin, with small quantities of free butyric and acetic acids, and a peculiar substance called 'gaduin.' Its efficacy as a medicine has been ascribed to small quantities of iodine and bromine, but it is more probable that it acts merely as a fattening food.

The solid animal *fats* are, like the animal oils, present in the living animal in the liquid state, but have a fusing-point so high that they are solid at the ordinary temperature of the air. They are obtained by boiling the tissues containing them with water, when the fused fat rises to the surface, and is thus separated from the fibrous connective tissue with which it was mixed. They differ from one another chiefly in the proportions of stearin, palmitin, and olein, which they contain. The olein can be to a great extent removed by pressure at a low temperature; what is left as a solid after thus squeezing out the olein, may be further separated into stearin, and a substance, fusing at a lower temperature, called 'margarine.' This was formerly supposed to be a distinct fatty substance, the glyceride of 'margaric acid,' but has been proved by Heintz to be a mixture, or perhaps a compound, of stearin and palmitin.

As an appendix to the animal fats and oils, we may mention two important substances which resemble them in many respects, but which are not usually classed along with them, as they are not 'glycerides.' These are 'spermaceti' and 'beeswax.' *Spermaceti* is a fatty substance found in cavities in the head of the sperm-whale (*Physeter macrocephalus*), and in some other allied whales. When freed from adherent sperm-oil, it is a colourless, inodorous substance, fusing at from 100° to 115° F. By dissolving in alcohol, and crystallising, pure 'cetin' can be obtained, fusing at 122° F. It is a compound ether or 'ester' (see CHEMISTRY) of palmitic acid and cetylic alcohol ($C_{16}H_{34}O$), and stands to cetylic alcohol in the same relation as palmitin does to glycerine.

Beeswax is a yellowish substance secreted by bees, and used by them in the formation of their cells. When exposed in thin layers to air and sunlight, it is bleached, and becomes white. It is a mixture of three distinct substances, which can be separated from one another by means of alcohol: 1. Myricin, insoluble in boiling alcohol; 2. Cerotic acid, soluble in boiling alcohol, but crystallising out on cooling; and 3. Cerolein, which remains dissolved in the alcohol after it has cooled. Myricin is a compound ether of palmitic acid and melissic or myricylic alcohol ($C_{30}H_{62}O$). Cerotic acid has the composition $C_{27}H_{54}O_2$. Cerolein is a soft substance, fusing at about 84° F. the constitution of which has not been exactly made out; wax contains only 4 or 5 per cent. of it.

SOAP

is formed along with glycerine when a fat or fatty oil is boiled with a *fixed caustic alkali*, such as caustic potash or caustic soda. Soap, therefore, consists (see CHEMISTRY) of salts of the oily and fatty acids, with potash or soda as a base. The soap can be separated from the watery liquid by the addition of common salt. The soap being insoluble in salt water, separates as a curd, while the glycerine remains dissolved in the salt water.

Soaps may be classified according to the base present, as 'hard soaps,' containing soda; and 'soft soaps,' containing potash. They may be further classified according to the acids or mixture of acids from which they are derived. Thus, there are oleic soaps (oleates of potash or soda), palmitic soaps (palmitates of potash or soda), and stearic soaps (stearates of potash or soda). Further, many of the soaps of commerce contain various ingredients mixed with them, either to increase their detergent action, or as mere

adulterations to add to the weight of the article. We shall here describe the chief varieties of soap which occur in the market, and the ways in which they are prepared.

HARD SOAPS.—These are prepared by boiling non-drying oils or solid fats with caustic soda solution. The oil or fat is first boiled with a quantity of alkaline solution insufficient for its complete saponification; when all the alkali has disappeared, salt is added, and the soap and excess of oil or fat rises to the surface, floating on the 'spent lye,' as the solution containing salt and glycerine is called; which, if the boiling has been properly conducted, contains no alkali. When complete separation has taken place, the spent lye is run off. More caustic soda solution is then added, and the boiling continued until the mixture has a permanent and strong alkaline taste and reaction. Salt is then added, which causes the separation of the soap from the alkaline solution. The soap is ladled out into what are called 'frames,' in which it cools and solidifies. The 'frame' is a box, the bottom of which is pierced with holes, and the sides of which are held together by means of bolts, so that they can easily be taken asunder. A stout cloth is placed on the bottom of the frame, allowing water to pass through, but retaining the soap. When cool, the sides of the frame are removed, and the mass of soap cut by means of wires into slabs and bars.

The oils and fats chiefly used for hard soaps are olive-oil (in France and Italy), tallow, palm-oil, and coco-nut oil. Coco-nut-oil soap has two peculiarities which deserve notice: 1. It is not easily 'salted out,' as it is soluble in solution of salt, unless this is very strong. It can, therefore, be used for washing in salt water, and is hence called 'marine soap.' 2. It can be combined with a very large quantity of water without appearing moist or becoming soft. All hard soap contains water; but if a manufacturer introduces more than 28 or 30 per cent. of water, the adulteration is at once made known by the softness of the soap in all cases where coco-nut oil has not been used. Cases have been observed of soap containing 75 per cent. of water and still preserving a tolerably firm character. Such 'dropsical' soap could not be sold were it not for the peculiar character of coco-nut oil.

Rosin Soap or Yellow Soap.—Rosin is a mixture of several acids, which form, with soda and with potash, salts resembling soap. They cannot be used alone; but when mixed with tallow soap or other hard soap, a useful mixture is produced, called yellow or brown soap. The proportion of resin to fat should not exceed 20 or 25 to 100.

SOFT SOAP is prepared by boiling oil (whale-oil, seal-oil, linseed-oil, or tallow) with solutions of caustic potash. It forms a soft glairy jelly, and contains from 40 to 50 per cent. of water. It is not separated from the lye by means of salt, because double decomposition takes place when salt (chloride of sodium) is mixed with soft soap (oleate, &c. of potash), chloride of potassium and hard soap (oleate, &c. of soda) being formed. A mixture of potash and soda soaps is now extensively used as soft soap. It is formed by boiling the tallow or oil with a mixture of caustic potash and caustic soda solution in the proportion of about 4 to 1.

TOILET SOAPS are either ordinary soaps carefully prepared from pure materials, and refined by boiling with salt water, or soaps prepared by mixing almond-oil or lard with *cold* caustic soda solution. They are perfumed by the addition of some volatile oil, such as oil of lavender, bitter almond-oil, &c.

The detergent action of soap depends upon the fact, that it is partially decomposed by water, caustic alkali being set free. The same property belongs to some other salts of the alkalies, the silicates, for instance; and a mixture of ordinary soap with silicate of soda (or, for soft soaps, silicate of potash) is now manufactured on a large scale under the name of 'silicated soap.'

MIXED SOAPS.—Many plans have been devised for mixing various substances with soap, with a view to reduce the cost of production. This reduction is, however, in most cases more than balanced by the reduction in the value of the article; the additions cost *something*, and are usually of *no* use.

When soap is mixed with 'hard water,' that is, water containing salts of lime, double decomposition takes place, and an insoluble curdy substance, 'lime soap' (oleate, &c., of lime), is produced. The waste of soap caused by the use of hard water is therefore proportional to the quantity of lime present in the water.

ALCOHOL.

The process of fermentation is described in the paper on CHEMISTRY. We shall here describe the various alcoholic liquids, and explain as far as possible the chemical differences between them.

WINE is the fermented juice of the grape. The juice of the ripe grape contains water, from 75 to 80 per cent.; glucose (grape-sugar), from 10 to 20 per cent.; tartaric acid, partly present as bitartrate of potash, from a half to two per cent.; albuminous matter, vegetable jelly, and tannin, about one per cent. The colouring-matter of the red wines is derived from the skins. During the fermentation, the glucose is partially transformed into alcohol and carbonic acid. The more completely this change takes place, the 'drier' is the wine. As already explained (see CHEMISTRY), the presence of the alcohol renders the bitartrate of potash insoluble; and the more alcohol a wine contains, the less bitartrate can it retain in solution. A weak wine is, therefore, generally a sour wine. The peculiar odour common to all wines is caused by the presence of a volatile ether formed during the fermentation (œnanthic ether); the 'bouquet' of the wine, which distinguishes one wine from another, is no doubt due to the presence of various ethers, which, however, occur in such small quantities that their exact nature has not been ascertained.

To make good wine, the grape-juice should contain at least 20 per cent. of glucose. Now, it frequently happens that grapes otherwise suitable for making wine do not contain so much sugar, and this defect in sugar is very often accompanied by an excess of acid, so that the wine produced is both weak and sour. A great deal of controversy has prevailed as to whether a wine-grower is justified in improving artificially the juice of his grapes, so as to produce a wholesome and pleasant drink. We need not here enter into

the ethics of this question, which do not seem to present any great difficulty, but describe the methods used for obtaining good wine from grapes containing too little sugar and too much acid, and for increasing the quantity of wine obtainable from a given quantity of grapes. One method of improving the 'must,' or juice, is to evaporate away part of the water, either after pressing the grapes, or by allowing the grapes to dry partially before they are pressed. By this method the acid is concentrated as well as the sugar, and the yield is diminished.

The second method, that of Chaptal, consists in adding glucose, prepared from starch, so as to make up the quantity of sugar to 20 per cent. By this method the wine is strengthened, but the excess of acid remains. This may be cured by adding normal tartrate of potash, which forms with the tartaric acid bitartrate of potash, which is mostly precipitated.

A third method is now practised to a considerable extent. It is called *Gallising* (Ger. *Gallisiren*), from its inventor, Dr L. Gall. It consists in diluting the juice with water till it contains the right proportion of acid (about 6 parts in 1000), and then adding glucose to make it up to 20 per cent. By this means a juice is obtained, which, as far as the water, acid, and sugar are concerned, resembles the natural juice of a good grape. At first, it was feared that the bouquet of the wine would suffer by the dilution, but it has been found that the grape contains far more than enough of the materials from which the bouquet is formed to perfume all the wine that can be thus made. This discovery was made by M. Pétiot, who utilised it by introducing a method for greatly increasing the yield of wine. This method (Pétiotising) consists in pouring upon the 'marc,' or solid matter remaining after the juice has been expressed, a quantity of water containing 20 per cent of glucose, and allowing this to ferment: the resulting wine has the bouquet characteristic of the original wine.

Champagne and other sparkling wines are prepared by adding to young wine in the bottle a certain quantity of glucose, then corking them up, and allowing the added glucose to ferment; the carbonic acid produced dissolves in the wine. Cider and Perry are prepared from apples and pears in much the same way as wine is prepared from grapes.

Beer, ale, and porter consist of the fermented infusion of malt, flavoured with hops. The various kinds of malt liquor differ from one another in the amount of alcohol, of sugar, of extractive matter from the malt, and of bitter substance from the hop. The dark colour of porter is produced by the addition of malt dried at a high temperature, so that part of the sugar is converted into caramel.

DISTILLED SPIRITS—whisky, brandy, rum, gin, arrack, &c.—consist of alcohol and water, along with peculiar flavouring substances, either derived from the material used, or purposely added. Thus, the flavour of whisky is mainly due to the presence of small quantities of amylic alcohol; that of brandy, to œnanthic and other ethers from the wine; that of rum, to butyric ether. Gin is flavoured by adding oil of juniper-berries to a mixture of alcohol and water. The brown colour of brandy and rum is given to them by the addition of burnt sugar (caramel). The yellowish colour of whisky is caused by tannin absorbed from the casks in which it is kept.

The alcoholic fermentation is made use of in the manufacture of bread. Wheat-flour consists chiefly of starch and an albuminoid substance called gluten, which forms a stiff paste with water. When yeast is added to the dough, part of the starch is converted into glucose, and this fermenting gives alcohol, which escapes by the chimney of the oven, and carbonic acid, which forms bubbles in the dough, thus giving the bread its spongy character.

GUNPOWDER.

The invention of gunpowder was formerly ascribed to the Benedictine monk, Berthold Schwarz, of Freiburg, in Breisgau, who lived about the year 1334; but it is now certain that it was known much earlier, at least as far back as the eighth century.

The action of gunpowder depends upon the fact that, when kindled, it burns rapidly, giving out a great quantity of gas. If the combustion takes place in a closed vessel, an enormous pressure is produced, partly owing to the quantity of gas produced, partly owing to the high temperature to which it is raised. Many substances are known which have the same property, but some of them are unsuitable for the purposes of gunpowder, because they are too easily exploded, and are therefore dangerous; or are too expensive; or explode too suddenly, so as to shatter the gun-barrel; or give rise to products of combustion which act destructively on metal.

Thus, although there are, as we shall see, substances which for certain purposes may be used instead of gunpowder, and are even more convenient, still gunpowder retains its place for its own special use as *gun*powder.

Gunpowder is an intimate mixture of charcoal, sulphur, and saltpetre. The charcoal is prepared by heating soft wood (alder or dogwood) in a cylindrical retort (see CHEMISTRY). The sulphur is *distilled* sulphur. The nitre is recrystallised in small crystals, so as to allow the mother-liquor which contains the impurities (chiefly chlorides) to drain away.

The ingredients having been reduced to powder, and sifted, are roughly mixed in a revolving drum of gun-metal, and then in quantities of about 50 lbs. at a time, more thoroughly mixed in the 'incorporating mill.' Here the mixture is sprinkled with a little water, and rubbed and ground by means of two cast-iron rollers, working upon a cast-iron bed. After from three to five hours' grinding, the 'mill-cake,' as the mixture is now called, is removed, and exposed for a quarter of an hour between copper plates to a pressure of 70 tons per square foot. The 'press-cake' thus formed is then broken up into grains. The object of this granulation or 'corning' is to allow the powder to ignite rapidly by leaving spaces between the granules for the passage of flame. The powder is then passed through sieves of different sizes of mesh, so as to sort it into the various degrees of fineness. The grains are next polished or 'faced' by being shaken together in a revolving drum. The larger-grained powder is sometimes 'faced' with graphite (black-lead), a little of that substance being put into the drum along with the powder.

Prismatic powder and pellet powder are granulated by pressing the 'mill-cake' into prismatic or cylindrical moulds. The granulated powder is dried in chambers heated by means of steam. The dry powder is freed from dust by sifting in a revolving cylinder lined with canvas, or fine wire-gauze.

The proportion of the ingredients in gunpowder varies slightly, but there is, on the whole, a remarkable agreement, as will be seen from the following table:

	Nitre.	Charcoal.	Sulphur.
British government powder...	75	15	10
French " " ...	75	12·5	12·5
Prussian " " ...	75	13·5	11·5
Swedish " " ...	75	16	9

We have said that this agreement is remarkable; it is so, because the proportion has been arrived at purely empirically, and not from any theory of the action of the ingredients upon one another when the powder is fired. We are, indeed, ignorant of the exact nature of the chemical changes which take place during the ignition of the powder. We know that the oxygen of the nitre oxidises the carbon, and, at least partially, the sulphur, and that the gases given off consist chiefly of carbonic acid, nitrogen, and carbonic oxide; while the solid residue, part of which remains in the gun as fouling, the greater part escaping as smoke, consists chiefly of sulphate of potash and carbonate of potash. If these, the main products, were the only products, the action might be represented by the equation:

$$14KNO_3 + 4S + 12C = 4K_2SO_4 + 3K_2CO_3 + 8CO_2 + 7N_2 + CO.$$

But this would correspond to a gunpowder containing in 100 parts, nitre, 83·8; charcoal, 8·5; sulphur, 7·5; a proportion differing very considerably from that found to be most advantageous.

GUN-COTTON is formed by the action of a mixture of strong nitric acid and strong sulphuric acid upon cotton-wool (see CHEMISTRY). When pure, its composition is $C_6H_7(NO_2)_3O_5$. In preparing it, the greatest care requires to be taken to wash the acids thoroughly out of it. This is done in the manufacture of Abel's gun-cotton by washing the skeins of gun-cotton in water, drying in a centrifugal drying-machine, and reducing the gun-cotton to a pulp in a rag-engine similar to that used in paper-mills (see TEXTILE MANUFACTURES). The pulp is then beaten and washed in a 'poaching-engine,' drained, and moulded in any required form. Gun-cotton explodes at a much lower temperature than gunpowder. The latter requires a temperature of at least 600° F. to explode it, while gun-cotton *may* explode at 277° F. and cannot, under any circumstances, be heated to 400° F. without explosion. It has some great advantages over gunpowder: 1. It can be stored wet with almost perfect safety, and is as good as ever when dried again; 2. It produces neither smoke nor fouling when fired; 3. It does not heat the gun so much as gunpowder. On the other hand, the explosion is more rapid than that of gunpowder, so that the barrel is more strained. Gun-cotton is used for blasting, and Abel's compressed gun-cotton, fired by means of a *detonating fuse*, may be made use of for this purpose, even when *unconfined*—that is, laid loosely upon the mass which it is desired to break up. The detonating fuse used for this purpose is a quill or thin metal tube containing a few grains of *fulminate of mercury*.

Among the numerous other explosive substances, we shall only mention NITROGLYCERINE, or GLONOIN-OIL. This is prepared from glycerine (see CHEMISTRY) by the action of a mixture of strong nitric acid and strong sulphuric acid, and as it resembles gun-cotton in the mode of its formation, it does so also in its constitution. Its formula is $C_3H_5(NO_2)_3O_3$. It is a liquid heavier than water, burns quietly when a light is applied to a small quantity, but explodes with great violence when struck or ignited by means of a detonating fuse. Small quantities swallowed or absorbed through the skin produce very severe headache. As its liquid condition renders it in many cases unsuitable for blasting, it is now often used in the form of *Dynamite*, which is porous earth (or the like) soaked with nitroglycerine.

FULMINATES.—Fulminate of mercury, or fulminating mercury, is prepared by dissolving mercury in nitric acid, mixing the solution with alcohol, and gently warming the mixture. The salt crystallises out, and can be purified by recrystallisation. It is a white crystalline salt, having the composition $C_2HgN_2O_2$. It explodes with very great violence, when struck, when heated, or when touched with strong sulphuric or nitric acid. In the dry state it is an extremely dangerous substance. Fulminate of silver can be prepared in a similar way; it is a much more explosive and dangerous substance than the fulminate of mercury.

PERCUSSION CAPS are primed with a mixture containing fulminate of mercury, chlorate of potash, and either powdered glass or sulphide of antimony. Only a small quantity of this mixture is made at a time, on account of the danger of explosion.

LUCIFER MATCHES.—Common lucifer matches are tipped with a paste consisting of glue, in which there are mixed phosphorus and some substance which readily yields oxygen, such as chlorate of potash, peroxide of manganese, or peroxide of lead. When such a mixture is rubbed, the phosphorus takes fire. As it is difficult to kindle *solid* combustibles such as wood by means of the flame of phosphorus, the match is dipped in paraffin or sulphur, which, when volatilised by the heat of the phosphorus flame, is easily kindled, and in its turn kindles the wood.

SAFETY MATCHES, which ignite only when rubbed on a specially prepared surface, are tipped with a mixture of sulphide of antimony, chlorate of potash, and powdered glass, made into a paste with glue. This mixture is very easily kindled, but not so easily as to take fire when rubbed on any rough surface. The prepared surface is coated with a mixture of *red or amorphous phosphorus* (see CHEMISTRY) and powdered glass. When the match is rubbed on this, a small quantity of the red phosphorus takes fire, and kindles the mixture with which the match is tipped.

FICTILE MANUFACTURES.

We employ the term *fictile* (*fingo*, to make, or fashion) to designate the art of forming objects of use or ornament from plastic earthy materials. It applies to bricks and earthenware, whether sun-dried or burned by fire, to glass of all kinds, and, in a limited sense, to cement-work; for the beautiful imitations of ivory carvings produced by plaster of Paris and wax are known as Fictile Ivory.

EARTHENWARE.

In all probability, the first step taken by man in adapting the plastic character of clay to his wants was that of coating his rude hut of wattled branches with it, to exclude the wind and rain. The hardness such a covering would acquire by the drying effect of the sun, and still more, when it was, either by accident or design, brought into contact with fire, would soon teach him to extend its application, and employ it in the form of bricks and tiles, which we may therefore place first in our description of earthenware manufactures.

Bricks—Tiles—Drain-tubes.

Bricks formed of tempered clay, and artificially hardened by heat, have been used for building purposes from a very early period in the world's history. Anciently, bricks were of two kinds—sun-dried and fire-burned. The former were much used in the buildings of Egypt and Babylon—they are still used in the East. The humid climate of other countries, however, requires a more careful and certain hardening than that which the sun gives; hence the use of fire for this purpose. Bricks and other forms of moulded clay fire-burned are the *terra-cotta* of the Italians, and this name is rapidly becoming common in this country. Thus, a terra-cotta building is understood to be a brick structure with mouldings and other ornaments of burned clay. It was not till after the Norman Conquest that bricks were much used in this country. It was, however, in the reign of Henry VIII. that brick as a building material attained a high repute. Its use was mostly confined to the erection of large buildings, and in these a great amount of decorative effect was often produced. Mr Dobson, in his excellent treatise on *Bricks and Tiles* (London: Weale), refers particularly to the decorative details of the manor-house at East Barsham, and of the parsonage-house at Great Snoring as worthy of notice. He also gives an illustration of ornamental brick-work as exemplified in a house, No. 43 St Martin's Lane, London. Up to the period of the Great Fire in London, the dwelling-houses were chiefly composed of wood; after that event, the danger arising from this cause was obviated in some measure by the compulsory use of bricks, not only for the walls, but for the ornamental parts of the house. From this cause may be traced the erection of many fine specimens of brick-work throughout the metropolis. The minute tracery-work which abounds in many specimens, appears to have been executed by tools after the erection of the walls.

Up to the close of the last century, bricks were untrammelled by the Excise; by the 24 Geo. III. c. 24, a duty of 2s. 6d. per thousand was imposed on bricks of all kinds. This and other acts of parliament, which greatly restricted the manufacture of bricks in England and Scotland, and from which Ireland alone was exempt, were repealed in May 1850; since which time brick-making has progressed enormously, and they have been made of all sizes and shapes convenient for the builder.

The common superficial clay, which is so liberally spread over our island, must be familiar to every one. It is of various colours—yellow, red, or bluish, according to the amount of iron oxide which it contains—is more or less mixed up with sand and fragments of rock, and when softened, becomes plastic and tenacious. What is chiefly necessary is a due admixture of alumina and silica—that is, clay and sand; for though pure clay may be made into extremely hard bricks, they are apt to shrink and crack in the burning; while too much sand renders them brittle and friable. As to the presence of a little lime, magnesia, or oxide of iron, it is rather liked than otherwise, these materials giving agreeable colours to the finished article. For bricks, slabs, crucibles, &c. which have to resist the action of fire, some of the coal-measure or stratified clays are generally had recourse to; these, from their greater purity, and a certain percentage of silica, being susceptible of a more thorough baking. In England, the Windsor, Stourbridge, and Welsh fire-clays are esteemed the best—yielding those bricks of various shapes and sizes employed in the construction of drying-kilns, smelting furnaces, and other structures intended to resist intense heat.

From the process of brick-making varying in different localities, our space compels us to give merely a general notion of the manufacture. Bricks are of different qualities. Thus, the *marls* or *malms* of the London bricklayer are of a yellowish uniform colour and texture, prepared by an admixture of ground chalk; *seconds* are those less uniform in colour and texture; *cutters* are those made so soft as to be cut into form for arches of windows; *fire*-bricks are prepared to withstand the heat of fires and furnaces, and of such there are varieties known as *Stourbridge clinkers*, *Welsh lumps*, *Windsors*, &c.; *paving*-bricks, made for the purpose their name implies; *compass*-bricks, of a circular shape, for lining walls and chimneys; *Dutch clinkers*, at one time imported from Holland, but now made in England, a compact variety often used in stables, about six inches long, three broad, and only one in thickness.

After having decided on the locality of the brick-field, the first process is the removal of the earth-covering. The clay or brick-earth is then dug up, and placed in heaps, and turned over, to

expose the masses to the mellowing action of the winter air and frost. The next process is tempering the clay, that is, preparing it in the form of a homogeneous paste for the moulder. This is still effected in many districts by hand, turning it over and over, and treading it with horses or men. In the improved processes, tempering is effected by the use of revolving rollers, between which the clay is passed; or by what is termed a pug-mill. This consists of an upright conical tub, the small end downwards; in which a shaft, fitted with projecting knives or cutters, is made to revolve by horse-power. The knives knead and cut the clay, and force it through the bottom of the mill, where it is cut into lumps, and laid aside till required. Fig. 1 shews an improved form of pug-mill, known as Clayton's Archimedean knife pug-mill. Great care is taken at the outset to free the clay from all stones, pebbles, &c.; the presence of one of which, even of small dimensions, will cause the brick to crack in drying.

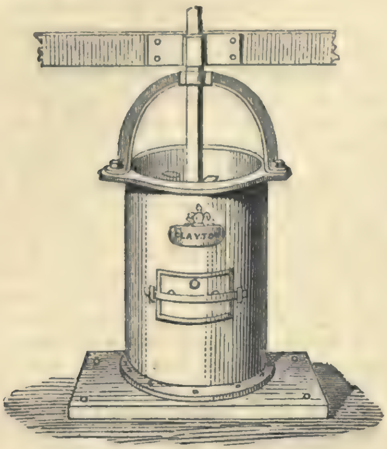


Fig. 1.

The next process is the moulding. The mould consists of a frame the size of the brick, without top or bottom, as *aa*, fig. 2. In the improved form of solid bricks, indentations, as *c*, are made in the upper and under faces of the brick (*b*, fig. 2). These form a 'key' to the mortar, securing efficient bond. To form this indentation, projections are made in the bottom of the mould and in the top. The moulder works at a bench; and his art consists in dashing in a lump of the tempered clay so as completely to fill up the mould, the superfluous clay being dexterously taken off with what is called the *strike*. To prevent the clay adhering to the mould, it is either dipped in water, or sprinkled with sand: if the latter, it is termed 'pallet-moulding;' if the former, 'slop-moulding.' In slop-moulding, two moulds are required, as the mould with its newly made brick is carried off by the attendant boy to the drying-ground, where the brick is deposited, the moulder the while forming another brick in a second mould, which is finished by the time the boy returns with the first.

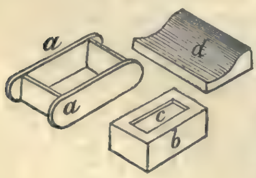


Fig. 2.

In pallet-moulding, one mould alone is used, the bricks being turned out on a pallet when made, and taken by the boy in a hack-barrow to the drying-floor. By slop-moulding, a man can make 10,000 per week; while by pallet-moulding, he can make as many as 36,000; in the latter case, however, the moulder has an assistant.

The next process, or that of drying, is one which requires considerable attention. 'The great point,' says Mr Dobson, 'to be aimed at is to protect them against sun, wind, rain, and frost, and to allow each brick to dry uniformly from the face to the heart.' The drying is sometimes effected under cover; but more frequently the 'hacks' are built in the open air, and covered with various substances, as straw, tarpaulin, &c.

The last process is the burning, which is performed either in *kilns* or in *clamps*—the latter being large square piles of bricks skilfully built up, with layers of fuel between, called *breeze*, and also with flues filled with coal, cinders, and wood, to facilitate still more the process of combustion. Baking in kilns, however, is preferable, as there is not only less waste, and less fuel consumed, but the bricks are sooner ready for the market. 'The kiln,' says Dr Ure, 'is usually 13 feet long by 10½ feet wide, and about 12 feet in height. The walls are one foot two inches thick, carried up a little out of the perpendicular, inclining towards each other at the top. The bricks are placed on flat arches, having holes left in them resembling lattice-work; the kiln is then covered with pieces of tiles and bricks, and some wood put in to dry them with a gentle fire. This continues two or three days before they are ready for burning, which is known by the smoke turning from a darkish colour to transparent. The mouth or mouths of the kiln are now dammed up with pieces of bricks piled one upon another, and closed with wet brick-earth, leaving above it just room sufficient to receive a fagot. The fagots are made of furze, heath, brake, fern, &c. and the kiln is supplied with these until its arches look white, and the fire appears at the top; upon which the fire is slackened for an hour, and the kiln allowed gradually to cool. This heating and cooling are repeated until the bricks are thoroughly burned, which is generally done in forty-eight hours. One of these kilns will hold about 20,000 bricks.'

Clamp-dried bricks require to be thoroughly dried previous to burning. Where kilns are used, the heat can be regulated so nicely that comparatively damp bricks may be put in, which are first dried by a gentle heat. In the clamp, as the heat is got up almost immediately, it would cause damp bricks to fly in pieces.

Slowly, machinery is superseding the hand-making of bricks, and it is more than probable that it would have completely done so long ere this but for the trade combinations of the workmen. Time, however, will bring this desirable change about, and bricks will then be produced at a cost far less than at present, and with extraordinary rapidity and superior excellence. A brick-making machine, made and worked by Mr Platt of Oldham, turns out ready for the kilns 140,000 bricks per week. The principle of brick-making by machinery differs considerably, from

the beginning, from that employed in the old and rude hand process.

The clay is brought as nearly dry as possible to the machine, and fed into large hoppers, and is made to pass through fluted rollers, which, whilst allowing the semi-plastic material to pass between them, reject all but very small stones. It is then carried through long drying-cylinders by Archimedean screws, the drying being effected by a powerful blast of air through the cylinders, of which there are two. At the end of the first, opposite to where the material entered, is another set of revolving rollers, which reduce the now drier lumps of clay into very small lumps, rejecting stones which were small enough to pass the first set: elevators lift it to the second drying-machine, after passing through which, it drops on to a kind of iron mechanical sieve, which rubs it into small grains, and rejects every fragment of stone which has escaped the other means of removal. It now passes, by means of a set of elevators, to a mill, which rapidly grinds it into a fine powder, and sends it down the wooden feed-pipes to the moulds: a jet of steam, however, meets it on its way down, so as slightly to moisten it before it reaches the moulds, which are of iron, and of the same size laterally as the bricks, but are much deeper vertically, so as to receive enough of the powdered clay to form a brick when the moulds are filled. Plungers of iron come down and press the powder into a compact hard brick, ready to be conveyed immediately to the kiln for burning. The various contrivances connected with this machinery are simple, but ingenious: each operation of the plungers forms two bricks, the moulds being in pairs; and although, from the length of the drying-cylinders (60 feet each), the machine occupies great space, yet the process is so regular, that, with a proper supply of clay, the moulding of the bricks at the end is very rapid and regular. The bricks made by the machine are truer, harder, and heavier than those made by hand. There is reason to believe that they will also prove more durable.

Tiles are prepared much in the same way as bricks; only, from their being thinner, and of a more intricate form, they require to be made of finer and tougher materials, and are always burned in kilns. They are of different kinds, according to the use to which they are applied—as *plain* and *pan* tiles, *ridge* tiles, &c. In fig. 2, *d* shews the form of the mould for a 'pan-tile.'

Drain tiles and tubes are always made by machine: the former are of a horse-shoe shape, and are made by rolling out the clay into sheets between two cylinders, and thereafter cutting out the necessary oblong parts, and bending them into the proper shape by an ingenious assemblage of endless chains, levers, pulleys, &c. The tubes are made by pressing clay from a cylinder through dies of the size and shape of the tube wanted, the cutting off of the lengths being also effected by the machine. Hollow bricks, now so much used, are also made by machinery. In fig. 3 we give diagrams of the dies used for forming various hollow articles: *a* is the die for the hollow brick shewn in perspective at *e*; *b*, a die for a circular drain-tube; *c*, a die for a drain-tube with flat bottom; and *d*, a die for a form of hollow earthenware brick used for fire-proof staircases. In all these, the clay is forced through the spaces represented white; the shaded parts being the iron portion of the dies. A very great variety of machines have been introduced for this branch of the earthenware manufacture.

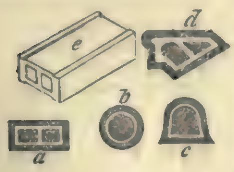


Fig. 3.

For architectural decorations, figures, vases, &c. on a large scale, known by the name of *terra-cotta*—literally, baked clay—various kinds of clay are used, but in this country those chiefly from the coal-measures. These are worked into a homogeneous paste, which is modelled or cast into the figure required, then slowly dried in the air, and ultimately fired to a proper hardness in a proper kiln. Tobacco-pipes are made of a finely ground white plastic clay, called *pipe-clay*, chiefly found near Wareham in Dorsetshire. This clay being worked into paste and dough, in the same manner as the finer sorts of potters' stuff, is next rolled into cylinders for the stems, and into balls for the bowls. These are then pressed to the desired form in metallic moulds, and pierced with a wire; dried for a day or two, scraped, polished, and dipped; and ultimately fired in a baking-kiln for ten or twelve hours. A clever workman, aided by a boy, can easily make from five to six gross of plain pipes per day.—For *Meerschaum*, see USEFUL MINERALS.

Pottery,

or the art of making vessels for use out of ordinary clay, was probably the earliest effort at artistic manufacture made by man. From plastering clay on his rude hut, he would learn much of its qualities, and could hardly fail to see that it could be of use to him if moulded into forms which would hold water, or in which he could cook his food. At first, there is no doubt such rude vessels were simply moulded by hand, and sun-dried; but in time, the perishability of these vessels would lead to their being fire-burned instead, and durability would be thus attained. But as great a revolution would be accomplished when the difficulty of turning so soft a material round at the same time the hand was fashioning it into shape, led to the adoption of a disk of wood on a pivot, probably at first placed in a hole in the ground, and so introduced the idea of the potter's throwing-wheel, the most simple, and, for the purpose, the most effective machine in use. It is now placed on a bench, for greater convenience, and turned by a wheel and band, as in fig. 5; but in other respects it has hardly been altered since its original invention.

The next great stage in the manufacture of pottery was the discovery of the art of applying a vitreous glaze over its surface, and thus rendering it more impervious to moisture, and also more beautiful. This is of great antiquity, and so is the art of enamelling pottery: the latter was extensively practised by the ancient Egyptians and Assyrians; whilst the former is constantly met with in the remains of the earliest and best periods of Greek and Roman pottery. Some of the enamels and glazes used by the ancients are of so fine a quality that they are even now unsurpassed. For a long time, during the decline and fall of

the Roman power, the art of glazing seems to have been lost, or was only known in Europe to the Moors, who practised it in Spain in the eighth century, chiefly for the decoration of their beautiful wall-tiles (*Azulejos*). They possessed the art of applying metallic and iridescent glazes of great beauty. When they were expelled from Spain, they carried their manufacture of pottery into the Balearic Isles, and for a considerable time, Majorca was its chief seat; whence the beautiful painted and glazed pottery of that and subsequent periods has been called Majolica, or Maiolica; the latter name is now rising in favour amongst connoisseurs. From Majorca it was introduced into Portugal, Italy, and France, and thence into Holland. In the seventeenth century, a pottery was established at Burslem, in Staffordshire—at which, however, only the coarsest articles of brown ware were manufactured. Subsequently, the glazing of this ware by the vapour of salt—obtained by throwing handfuls amongst the heated articles in the kiln—was introduced by Mr Palmer; and in this state the manufacture continued till 1690, when two Dutchmen of the name of Elers commenced at the same place the fabrication of red unglazed porcelain, of black or Egyptian ware—the tint of which was produced by manganese—and of brown ware of a higher glaze and finish than had hitherto been produced in England. Some years afterwards, Mr Astbury was led by accident to attempt the admixture of ground flint with the finest white clay—a composition which yielded not only a finer and whiter, but a more durable ware than had previously been manufactured. It is to Josiah Wedgwood, however, that Britain is mainly indebted for the vast improvements which have taken place since the middle of last century in this department of her manufacturing industry. It was he who erected the first large factories in Staffordshire, and who, from his extensive chemical and mechanical knowledge, conjoined with correct taste, has made the stoneware manufactures of this country superior to those of every other.

Under the general designation of pottery are included three different kinds—namely, *earthenware*, *stoneware*, and *porcelain*, but it is frequently applied specially to earthenware, to distinguish it from the other two varieties. In this sense, it means those ceramic manufactures made from natural clays, or from clays with the addition of sand or calcined flint; whilst stoneware is made of clay with a considerable addition of pure silica, usually obtained by grinding down blocks of decomposing Cornish granite, and some lime; and porcelain is a compound of kaolin or China clay, or decomposed felspar, with pure silica and other materials in various proportions to form the various qualities.

The best clay for pottery manufacture is obtained in Dorsetshire, and another of a quality somewhat inferior is found in Devonshire. These clays are both well suited for the potter, being easily worked, standing the fire well, and becoming very white when burned. When dug, the clay should be cleansed as much as possible with the hand, and freed from stones. At the factory, it is cut to pieces, and put into a cast-iron cylinder, about four feet high and twenty inches in diameter. An upright shaft or axis revolves in this cylinder, from which knives radiate in all directions, being so placed that the shaft with the knives attached somewhat resembles a screw. In the sides of the cylinder, knives are also fixed, which reach nearly to the shaft, and remain inactive. When the shaft moves round, the active blades cross the passive, and operate like shears in cutting the clay, which is by this process reduced to a fine paste. The external appearance of the machine much resembles the 'pugging-mill' in fig. 1. When well ground in this manner, the clay is reduced by water to the consistence of cream, and is run off through sieves of wire, lawn, and silk, so that none of the grosser parts may enter into the composition of the ware. This clay-cream, or *slip*, as it is termed, is then diluted to a standard density, and set aside in cisterns, to be used as required.

The clay thus prepared possesses remarkable plasticity; it is sensitive to the slightest pressure, and retains any form or impression given to it. But this high degree of plasticity brings with it sundry inconveniences: thus, in the firing, the articles are apt to crack, and also to become distorted. This distortion does not arise, it is supposed, merely from the evaporation of the water, but from the tendency of the particles to assume their normal condition, out of which they were forced by the processes of pressing and twisting, or 'throwing,' to which the clay is subjected. To prevent this cracking and distortion, it is necessary to add some silicious substance, incapable of contraction, to the clay. Ground flint is most commonly used for this purpose. It is prepared by cleaning the flint found imbedded in chalk, subjecting it to a red heat, and throwing it in this state into water, by which it becomes comparatively soft. It is then broken by being placed under upright shafts, which move up and down in a frame, and are called *stampers*. The broken flint is next transferred to the flint-mill, which consists of a strong wooden tub, built round a circular bottom, composed of flat pieces of hornstone. On the top of these, similar flat stones are laid, which are attached to, and driven by, strong wooden arms projecting from an upright shaft in the centre of the box. Into this tub the flint is put, and a stream of water is constantly running in, which greatly facilitates the grinding. In fig. 4, *a*, *a* represent the revolving arms, and *b*, *b* the stones fixed to them. When the flint is reduced to about the consistence of cream, it is passed through sieves, in a manner similar to the clay.

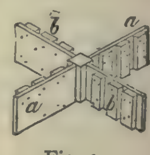


Fig. 4.

The flint and clay liquids being properly prepared, they are next mixed together in such proportions that the flint will be to the clay as one to five or six, according to the plasticity of the clay. Sometimes a little Cornish stone is also added; and the following are the proportions generally adopted in one of the principal Staffordshire factories for what is designated *cream colour:* Silex, or ground flint, 20 parts; clay, 100 parts; and Cornish stone, 2 parts. This mixture is put into oblong stone troughs, called *slip-kilns*, bottomed with fire-tiles, and placed above a furnace flue. Heat is then applied, and the water gradually evaporated, the liquid being constantly stirred during the operation. By this process, the mixture is formed into a fine uniform

doughy mass, which is cut into pieces, and heaped together in a damp cellar, where they lie for the space of about six months. The clay here becomes black, exhales a fetid odour, and undergoes a slight degree of fermentation, during which carbonic acid gas and sulphuretted hydrogen are disengaged. This improves both the colour and texture of the clay, and tends to bring it to a homogeneous mass. The longer the clay-paste is kept, the finer it becomes in the grain; and vessels made from it, when old, are not so apt to crack as those formed from newer paste.

The process of firing, as generally carried out, is a very wasteful one as regards the expenditure of fuel, and is attended with inconveniences. In view of these, more perfect processes have been introduced to get rid of the superfluous water: amongst others, we may notice the screw-press, and filtration by means of a vacuum; more recently still, a hydraulic press has been introduced, which is rapidly superseding other appliances.

To assist in forming the clay into a fine mass, the operation of sloping or wedging is performed at intervals during the period the clay is lying to ferment. This consists of slicing the clay with a spade, and dashing the slices together so as to expel the air which lodges in the mass. This process in large establishments is aided, or performed, by passing the clay through a mill. The last process previous to the throwing is the 'slapping,' which is performed by cutting masses into portions by means of a wire, provided with handles at its extremities, and dashing the pieces together again, care being taken to make them join parallel to each other; if this is not attended to, the grain being disturbed, the pieces are likely to crack during the process of baking.

The clay, being thus completely kneaded, is put upon the potter's wheel (fig. 5), where it is formed

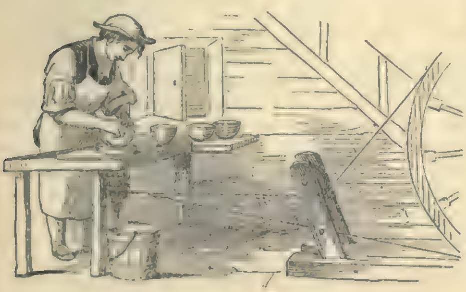


Fig. 5.

into articles of various shapes. This lathe consists of an upright iron shaft, the lower point of which turns in a socket, and the upper is fixed in a broad wooden disk. Near the top, the shaft passes through a socket attached to the framework of the lathe. In the centre is a pulley, with grooves of different circumferences, by which the speed of the shaft can be increased or lessened as circumstances require. This shaft is driven by a fly-wheel, from which an endless belt passes to the pulley. The clay is weighed out and handed to the workman at the lathe, called the *thrower*, who dashes the mass upon the revolving wooden disk. He then dips his hands frequently into a dish of water placed beside the lathe, and pressing the clay with both hands, it gradually assumes an irregular conical form. By pressing one hand upon the top of this cone, it is again flattened down to a cake, by which operation all air-bubbles are extricated. He next lessens the speed of the shaft by shifting the belt from a small to a larger groove in the pulley, and with his hand forms the clay into the shape of the vessel required. This operation is called *throwing;* and when performed, the vessel is cut off from the disk by a wire attached at each end to a piece of wood. The vessel is then allowed to dry gradually, until it arrives at a certain point called the green state; after which it is put upon a turning-lathe, similar to that used by the worker in wood. Here it is turned to its proper shape by a sharp tool, which also smooths it, and after this, it is burnished with a steel surface.

In the green state, also, are attached handles and other appendages to vessels, this being the point at which the clay possesses its greatest tenacity. Handles of tea-pots, &c. are formed by squeezing the dough through different-shaped orifices, which, as it issues, is cut into proper lengths, and bent into the desired forms. These being formed, are attached to the vessels by a paste called *slip*, and the seams are smoothed off with a wet sponge. The ware is next placed in an apartment heated to about 90° F. and fitted all round with shelving. When completely dry, they are rubbed over, and are then ready for the baking-kiln.

The articles made in the manner above described are all of a round form; but there are many which are of a different shape, and require a different process in the manufacture. Oval-shaped vessels are formed by what is called *press-work*, which is done in moulds made of plaster of Paris. One half of the pattern is made in the one side of the mould, and the other half in the other side. The parts are formed to fit each other exactly, and are joined in the same manner as the handles are to vessels. Imitations of flowers and foliage, and all delicate pieces of ornamental ware, are *cast* in moulds of plaster of Paris. The clay is poured into the mould in a thin state, and is there left for a certain time.

The plaster absorbs the water of that portion which lies nearest to it, and solidifies the mixture of clay and flint; the central fluid portion is then poured out, and the film or coating of clay left to dry. Another portion of fluid clay and flint is then poured in, which is passed through the same process as before. The mould is placed in a stove, and after being dried, is touched up and rendered perfect in outline by a modeller.

Plates, saucers, wash-bowls, &c. are made by the process called 'flat-ware pressing.' A mould, *bb* (fig. 6), is made, which gives the outline of the internal shape of the article; and a profile-plate, *cc*, that of the outside. The latter is mounted upon a frame or carrier, by which the depth can be adjusted so as to give any desired thickness to the material. The mould, *bb*, is placed upon a whirling-table, *aa*, and the clay is pressed down upon its surface, and moulded by the hands till it assumes the proper shape. Where an exact

Fig. 6.

outline is required, the profile-mould is used. The thickness of the material is represented by the white space between the outlines *b* and *cc*, fig. 7.

When the ware is ready for the kiln, the articles are placed in baked fire-clay vessels called *seggars* or *sags*. These vessels are made of inferior clay, by the workmen during the intervals of their work, and are from six to eight inches deep, and from twelve to eighteen in diameter. The sags are packed full of the dry ware, and are then piled above each other in the kiln, the bottom of one sag forming the cover of another. These rude earthenware boxes are necessary, to prevent the ware from being suddenly and unequally heated, and also to protect it from the smoke and dust of the kiln.


Fig. 7.

Fig. 7 represents one method of packing articles in the sags. *aa* is a section of a sag, provided with projections on which the article, *bb*, is suspended. In the inside of this, a second article may be placed, as the jug, *c*, shewn by the dotted lines. A second sag, as *dd*, is placed above the first, the bottom forming the cover or top to *aa*. In packing flat articles, as plates, little pieces of clay, of various shapes, as shewn at *a*, *b*, *c*, fig. 8, and known as cock-spurs, stilts, &c. are placed between the articles, as shewn at *d*, fig. 8; this keeps each article separate.

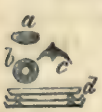


Fig. 8.

The body of a pottery-kiln is generally of a conical shape, covering and protecting from the weather the fire-kiln, which is circular, and provided with a domed top, as *aa*, fig. 9. The furnaces, six or eight in number, are placed equidistantly round the kiln, as *b*, *b*. The smoke escapes through the apertures made in the dome. The door for obtaining access to the interior is shewn at *c*. When the kiln is filled with the sags, it is built up, and fire applied to the furnaces. The heat is increased gradually, from the time the fire is put on, till the ware is found to be properly burned. To ascertain this, the workman draws from the kiln what is called a *watch*, and if this is found to resemble in colour a previously burned vessel, he allows the kiln to burn a little longer, and then opens the doors of the furnaces carefully, so as to lower the heat by slow degrees. The burning, or *baking*, as it is called, usually lasts from forty to forty-two hours, after which the kiln is allowed to cool very slowly. When the ware is taken out of the sags, a child makes the pieces ring with the handle of a brush, used for dusting them, to test their soundness, and then immerses them in the glazing material. The glaze is kept in a large tub, into which the articles are put by the child, and lifted out by a man, who shakes them in the air, and places them on a board, to be conveyed to the glazing-kiln.

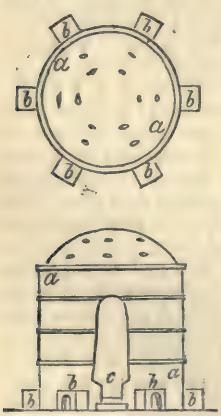


Fig. 9.

'Three kinds of glazes,' according to Dr Ure, 'are used in Staffordshire—one for the common pipe-clay or cream-coloured ware; another for the finer pipe-clay ware, to receive impressions, called *printing body;* a third for the ware which is to be ornamented by painting with the pencil. The glaze of the first, or common ware is composed of 53 parts of white-lead, 16 of Cornish stone, 36 of ground flints, and 4 of flint-glass: of the second, 26 parts of white felspar, fretted with 6 parts of soda, 2 of nitre, and 1 of borax; to 20 pounds of this fret, 26 parts of felspar, 20 of white-lead, 6 of ground flints, 4 of chalk, 1 of the oxide of tin, and a small quantity of the oxide of cobalt, to take off the brown cast, and give a faint azure tint, are added. As to the ware which is to be painted, it is covered with a glaze composed of 13 parts of the printing colour fret, to which are added 50 parts of red-lead or litharge, 40 of white-lead, and 12 of flint; the whole having been ground together.'

The above compositions make a very clear, hard glaze, which is not affected by vegetable acids, and preserves its lustre for an indefinite time. When covered with the glaze, the vessels are put into sags, which have been previously glazed with a composition of 13 parts common salt and 30 parts potash. They are then put into the glazing-kiln, which is usually smaller than the biscuit-kiln, the sags being piled in the same manner as at the first burning. The heat of the glazing-kiln is very low at first, but gradually increases until it reaches the melting-point, when great care is necessary to prevent the temperature from suddenly falling. To ascertain when the temperature is high enough, balls of red clay, coated with fusible lead-enamel, are employed. When these balls become of a slightly dark-red colour, the temperature is sufficient to glaze ordinary pipe-clay ware. The fire is kept on for about fourteen hours, after which very little fuel is added, and the kiln is gradually allowed to cool. The vessels are again tried by being slightly struck by a small wooden hammer, when, if they ring freely, they are sound.

The colouring of pottery is performed either by what may be called painting, or by printing. The colours used in producing the *dipt* or *sponged* ware are of a very cheap kind, as it is only employed for common purposes. In dipt ware, the colours are dropped on before the ware is burned; and in sponged ware, when it is in the biscuit state. A black dip is made from manganese, ironstone, and clay-slip; a drab, by nickel and slip; a blue, by cobalt and slip; a yellow, by yellow clay alone, or by a compound of red and white clay; and a red, by a natural red or brown clay, which will burn red.

The colours used for painting and printing on ware are similar to one another, excepting that the colours for printing are more carefully prepared; both, however, form an important and extensive part of the materials of a pottery. The manufacturers of earthenware are much occupied with the improvement of the variety and beauty of the colours, as well as of the patterns or styles that are produced, and hence a great emulation exists among those employed in the trade. The blue colour in *printing* is produced from cobalt, which is used with flint, ground glass, pearl-ash, white-lead, barytes,

china-clay, and oxide of tin in reducing its strength; the brown, by ochre, manganese, and cobalt; the black, by chromate of iron, nickel, ironstone, and cobalt; the green, by chrome, oxide of copper, lead, flint, and ground glass; and the pink, by chrome oxide of tin, whiting, flint, ground glass, and china-clay, which are mixed in various proportions, fused together at a high temperature, then pounded and mixed with oil. The colouring matter is ground upon a porphyry slab, with a varnish prepared from a pint of linseed oil boiled very thick, four ounces of rosin, half a pound of tar, and half a pint of the oil of amber. This transfer varnish is very tenacious, and requires to be liquefied by heat before being used.

The figure or design to be fixed upon the vessel is engraved in the usual way upon copper-plate, which is rubbed over with the colouring matter prepared as above, and the impression is taken upon a thin unsized paper made for the purpose. The printed paper is placed upon the vessel, and is rubbed with a roll of flannel about an inch and a half in diameter. After this the vessel is set aside for a little, to allow the figure to become fixed, when it is dipped in water, and the paper washed off with a sponge. The impression being transferred, the vessel is dipped in alkali to destroy the oil, and then immersed in the glazing matter. Printing above the glaze is performed by covering the copper-plate with the colouring matter as before, and brushing off what is superfluous. A cake of glue, stiff enough to be handled, is then laid upon the plate, which receives the impression of the figure. The glue cake must be very cautiously lifted off from the plate, and transferred to the surface of the glazed ware which it is intended to print. The same cake will answer for transferring a number of impressions, by simply washing its surface.

STONEWARE.

This is a ware intermediate between common earthenware and porcelain, and may be described as a coarse kind of porcelain. The glazing for the commonest kinds is performed by throwing common salt into the heated furnace; this is volatilised and decomposed by the joint agency of the silica of the ware and of the vapour of water always present; hydrochloric acid and soda are produced—the latter forming a silicate which fuses over the surface of the ware, and gives a thin but excellent glaze. The salt is not thrown in until the kiln has been raised to its greatest necessary temperature.

Stoneware of the Wedgwood kind is a semi-vitrified ware, which is not susceptible of a superficial glaze. It contains barytic earths, which act as a flux upon the clay, and form an enamel, or by the clay being rubbed over with a compound vitrifying paste. Messrs Doulton and Watts, of the Lambeth Pottery, London, have lately made great advances in the manufacture of stoneware, both for ornamental purposes, and for those of utility only.

PORCELAIN.

Porcelain, or china, as it is most frequently called, from the circumstance that our first knowledge of it was derived from specimens imported from China, is a fine compact, hard, and translucent ware, of which there are two distinct varieties. The one is *hard*—the *pâte dure* of the French potters—and the other soft or tender—*pâte tendre*. Strictly speaking, they may be said to consist of silica, alumina, and potash (hard porcelain), and silica, alumina, and soda (soft porcelain). The ingredients, however, vary considerably, according to the skill or requirements of the potter. The glaze used for the *hard* variety is composed of a glass with an earthy base; but that for the *soft* always contains some metallic substance, usually lead.

Kaolin-clay is the largest ingredient in porcelain ware. It is composed of alumina and silica, and is obtained in large quantities in China, Germany, France, and in the county of Cornwall in England. Kaolin is very friable in the hand, and is with difficulty formed into a paste or dough which will bear to be worked. That found in Cornwall is whiter than the foreign clays, and more unctuous to the touch. It is a decomposed felspar—one of the constituent minerals of granite—which has accumulated in vast quantities in certain localities, having been no doubt washed down by rains from the weathered and exposed surface of granitic rocks. When the kaolin or china clay of Cornwall is mixed with alluvial matter, it is broken into lumps, and thrown into a running stream; this carries off the firm particles into catchpools, where the sediment is allowed to settle, and the water is drawn off, leaving the clay.

Among recent inventions in the manufacture of porcelain may be mentioned Parian or statuary porcelain, the beauty of which will doubtless be familiar to most of our readers through the medium of the reproductions of modern sculpture, on a reduced scale, by the celebrated firms of Minton & Co. and Messrs Copeland. The use of a soft felspar instead of the Cornish stone, is that which chiefly imparts the peculiar effect. Great care is necessary in producing articles of this material: they are generally cast in moulds, in a number of pieces; and as the process of firing contracts the size to a considerable extent, great skill on the part of the artist is called for. Unglazed porcelain has the appearance of marble or alabaster, and is much used for ornamental articles and statuettes. It is known by the name of 'biscuit.' In the adaptation of this material, the Sèvres manufactory in France has been long distinguished. The English manufacturers are, however, fast following them, if not already equal. Messrs Minton have succeeded in producing specimens of this manufacture, which, for their 'freshness of effect and excellent taste,' have attracted great attention. Parian porcelain far exceeds in beauty and softness the ordinary porcelain biscuit; the effect arises from the light penetrating to a certain depth, while in biscuit the light is reflected at the surface, giving it a 'cold appearance.'

In painting on porcelain, the same colouring materials are used as those employed in colouring glass or earthenware. In all the more delicate patterns, they are laid on with a camel-hair pencil, and generally previously mixed with a little oil of spike or oil of turpentine. Where several colours are used, they often require various temperatures for their perfection; in which case, those that bear the highest heat are first applied, and subsequently

those that are brought out at lower temperatures. This art of painting on porcelain, or *in enamel*, is of the most delicate description; much experience and skill are required in it, and with every care, there are frequent failures; hence, it is attended with considerable expense. The gilding of porcelain is generally performed by applying finely divided gold mixed with gum-water and borax; on the application of heat, the gum burns off, and the borax, vitrifying on the surface, causes the gold to adhere; it is afterwards burnished with bloodstone, agate, or other polishers.

There are some considerable manufactories of pottery in the north of England, and one or two in Yorkshire; but the principal site of both porcelain and pottery wares is in the modern borough of Stoke-upon-Trent, which contains a population of 100,000 persons engaged directly or indirectly in these manufactures. The principal seats of porcelain manufacture in continental Europe are Sèvres near Paris, Tournay in Flanders, Dresden, Berlin, and Florence; the wares of Sèvres being as yet unequalled in their translucency, glaze, and gilding, and in the elegance and taste displayed in their shapes and figure-paintings.

ENCAUSTIC TILES—TESSERÆ—MOSAICS.

The term *mosaic* is said to be derived from the Greek word *mousaikon*, elegant, or belonging to the Muses; and is now applied to the art of imbedding or inlaying in a cement fragments of different coloured substances, so as to produce the effect of a picture. This art was practised at a very early period, and was introduced into Italy by the Byzantine Greeks. Magnificent specimens are to be seen in many of the Italian churches, where precious marbles, agates, jaspers, avanturines, malachites, &c. constitute the coloured tesseræ, or small square fragments of which the work is formed.

The ancients applied mosaics chiefly to pavements, for which they are admirably adapted. Specimens of highly decorated pavements are also frequently met with in the grand ecclesiastical structures of the middle ages. Within the last thirty years, great and successful efforts have been made in this country to introduce encaustic and mosaic pavements: the latter, from the costliness of the labour required in setting small tesseræ, has not advanced much; but a very large trade has grown up in the former, and the designs of Messrs Minton and Hollins, of Messrs Maw, Mr Godwin, and others, are daily increasing in beauty and perfection; besides flooring, they are also being much used for wall-decoration and other purposes. The employment of small earthenware tesseræ for mosaic pictures has been carried out with great success by Messrs Minton and Hollins, at South Kensington and elsewhere. Both tiles and tesseræ are exceedingly hard and durable, and almost every kind of colour can be given to them; they are both made in the same way, their real difference being only in size.

Encaustic Tiles are made in this country in the same manner as machine-made bricks; that is to say, the various kinds of clay used are carefully prepared and ground to powder, which is slightly moistened, and pressed, usually by hydraulic machinery, into the moulds. Various designs are pressed into their upper surfaces by properly prepared steel dies attached to the plungers; and these impressions are afterwards filled in with differently coloured clays or enamels, reduced by water to the consistence of cream. As the moisture is absorbed, the surface is scraped down to a perfect level, and the tile is then burned. This process, with various modifications, is carried out chiefly in Staffordshire, Shropshire, and Herefordshire, for wall decoration; and for some of the finest qualities of floor-tiles, glazing is used the same as in stoneware, &c.

Florentine Mosaics are formed by a totally different process. A slab of stone, usually black marble, is finely polished, having been cut to the shape and size required. Upon this the design is drawn, and then cut out, so as to allow pieces of variously coloured stones to be inlaid, and, by their combinations, produce beautiful pictures. Some of these works, as seen in the Pitti Palace and other places, are of remarkable beauty. Those sold in the shops of Florence at comparatively low prices are often not quite genuine; instead of rare stones, coloured pieces of various sea-shells are much used.

Roman Mosaics.—These differ from both kinds mentioned; they are made of glass, and will be described amongst the manufactures of glass, which is the next portion of our subject.

GLASS.

The origin of glass-manufacture is involved in the greatest obscurity, and has given rise to much ingenious speculation, upon which little or no dependence can be placed. Glass beads have been found on the bodies of Egyptian mummies which are known to have been embalmed 3000 years ago. Pliny says that the art of glass-making was accidentally discovered by some shipwrecked Phœnician mariners, whose vessel was laden with fossil alkali, a component part of glass. On kindling a fire on the sand to prepare some food, and placing their cooking-vessels on pieces of the substance just named, the sand, by the agency of the fire and its union with the alkali, became vitrified; hence, according to this authority, the discovery of the art. This is the explanation of Pliny, and has answered its purpose until later times, when the closer examination of the mural pictures on the buildings of Egypt has shewn us—particularly in those of Thebes—that the Egyptians were accomplished glass-blowers; and our museums now contain marvellous instances of their handiwork.

The first glass-manufactory of any note in the Christian era was established at the village of Murano, near Venice. The glass produced there was superior to any in Europe, and for a long time the principal supply was obtained from thence. The Venetians were long celebrated for making glass mirrors, which they brought to considerable perfection. Window-glass appears to have been made in England in the middle of the 15th century, but it was of an inferior description. In 1557, the finer sort of window-glass was manufactured at Crutched Friars in London. The first flint-glass was made at Savoy House in the Strand; and the first plate-glass for mirrors, coach-windows, and the like, was fabricated at

Lambeth in 1673 by Venetian workmen brought over by the Duke of Buckingham.

A glass-house is usually built in the form of a cone, from 60 to 100 feet high, and from 40 to 80 feet in diameter at the base. The furnace is placed in the centre of the building, and is generally of an oblong figure, although sometimes circular. Below the furnace is an arched gallery, extending right across the building, and terminating in folding-doors, large enough to admit a barrow for carrying out the ashes, and to afford a sufficient draught of air to the furnace. In the sides of the furnace are apertures called working-holes, through which the blowing-tubes are inserted.

Crown-glass.

Crown or window glass is usually composed of alkali and fine white sand. The best sand for glass-making is that which contains most transparent particles, and this is found in large quantities in that brought from Lynn-Regis in Norfolk, and the western coast of the Isle of Wight.

Up to the beginning of the present century, the soda used in making glass was made from kelp, the ashes of burned sea-weed. But in 1792, Le Blanc discovered a method of converting common salt into carbonate of soda; thus affording to manufacturers a readily obtained and inexhaustible supply of alkali. From the introduction of this, a new epoch in the history of glass-making may be dated. The base of all glass is that above stated, but to the alkali and the silica (sand), lime and other ingredients are applied. The lime, in due quantity, promotes the fusion and improves the quality of the mass; but if too much is present, it renders the glass difficult to work, and subject to devitrifaction. Alumina, which is also sometimes added, and which is always accidentally present, renders the glass liable to devitrifaction. Iron, too, is present in the sand, and as this colours the glass, its effects are got rid of by the addition of manganese. When the soda is introduced in the form of sulphate, or Glauber's Salt, charcoal is introduced, to decompose the salt. Arsenic is also added to decompose other ingredients. The proportion in which these various materials—as sand, soda, charcoal, chalk, manganese, and iron—are mixed, varies with circumstances, and according to the skill of the manufacturer. To this mixture of materials, a portion of broken waste-glass, termed *cullet*, is added, to assist the fusion.

The pots in which these materials are placed, to be subjected to the action of the furnace, are all made by manual labour, being built up bit by bit, and occupy many months before being ready for

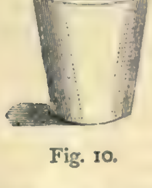


Fig. 10.

Fig. 11.

use. They are made of the best Stourbridge clay, moistened and mixed with about one-fifth of ground potsherds, are carefully dried for months, and thereafter exposed to the action of the kiln. Their shape is that of an ordinary flower-pot without a rim (fig. 10). Flint-glass is melted in pots of a different shape, as shewn in fig. 11. They are thus formed to protect the contents from the effects of the flame and smoke, which would bring about a chemical action, tending to reduce the metallic oxides used. The furnace in which the pots are deposited is circular in form, the fire-bars in which the fuel is consumed being in the centre, and nearly on a level with the floor of the glass-house. A series of subterranean passages are placed at various angles with the main or transverse passage, which serves as the ash-pit, a supply of air being thus obtained from different directions. The pots are placed round the circumference, at regular intervals, one on each side of a flue. An aperture is left in the brickwork, in the space between two flues, through which the materials are passed to the pots. The heat is regulated to any degree of intensity, by opening or shutting apertures admitting more or less air to the grate bars.

The materials are introduced into the pots by means of an iron shovel, the pots being previously brought to a white heat. The aperture is then closed with a stopper, and carefully luted with clay. After subjection for some time to a high temperature, the whole become thoroughly fused, and enter into chemical combination; the silica uniting with the bases, soda, lime, &c. (see CHEMISTRY) to form silicates. On the mass subsiding, fresh materials are added till the pot is filled with the molten glass, technically called *metal*.

The pots last for periods of greater or less extent—some for two, three, and even twelve months, while some give way during the preliminary testing to which all are subjected.

The pots being now full of melted glass, the material is ready for the operations of the workmen. An iron tube, six or seven feet in length, thicker at one end than the other, is heated and dipped into the liquid 'metal,' through the working-hole, as shewn in fig. 12. A portion of glass adheres to the thick end of the tube, which, being

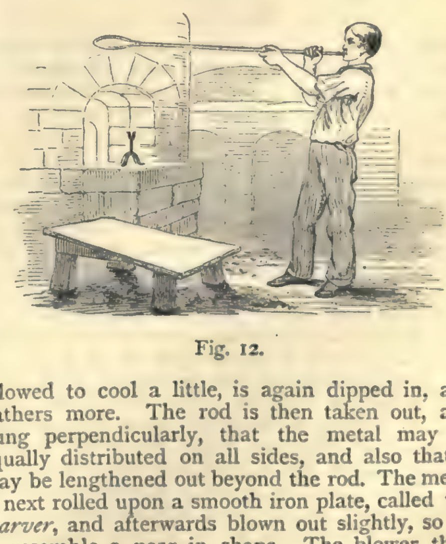


Fig. 12.

allowed to cool a little, is again dipped in, and gathers more. The rod is then taken out, and hung perpendicularly, that the metal may be equally distributed on all sides, and also that it may be lengthened out beyond the rod. The metal is next rolled upon a smooth iron plate, called the *marver*, and afterwards blown out slightly, so as to resemble a pear in shape. The blower then

heats the metal twice, blowing it out between the heatings, when it is brought to a globe shape. The glass is then allowed to cool a little, and a rod of iron, called the *punty-rod*, is attached to the side immediately opposite to the tube. This is done by dipping the end of the rod in the liquid metal, which adheres readily to the half-cooled glass, and the tube is detached by touching it with a piece of iron dipped in cold water, leaving an aperture in the glass about two inches in diameter. The glass is again put into the furnace until it has become sufficiently ductile to yield readily to any impression. The workman then twirls the globe round, slowly at first, but afterwards with great velocity, during which the aperture formerly mentioned gradually widens, until it reaches a certain point, when the globe suddenly flies open with a loud ruffling noise, and becomes a plane or circular sheet of glass, about fifty inches in diameter. This is an exceedingly beautiful operation, and requires considerable skill on the part of the workman. The circular motion is still continued, until the sheet is sufficiently cool to retain its form, when it is carried to the annealing-arch to be tempered. The punty-rod is detached by a slight blow with an iron tool, and the sheet of glass is lifted on a wide-pronged fork, and set up edgewise in the kiln. A kiln will hold from 400 to 600 sheets. When full, the mouth is built up, the fire withdrawn, and the kiln allowed to cool as gradually as possible. This process of gradual cooling is known by the name of *annealing*—a process without undergoing which, glass would be so brittle as to break on the application of the slightest force. The glass is then taken out, the circular sheet cut into halves, and assorted into different qualities, known by the names of *firsts*, *seconds*, and *thirds*.

The manufacture of crown-glass has rapidly declined of late years, owing to the introduction and perfection of sheet-glass, and especially of the means of polishing it, so that it may be made to have all the brilliancy and perfectly smooth surface of polished plate-glass.

Sheet-glass.

The process we have described is only applicable to crown or window glass; the manufacture of sheet-glass is very different. In making sheet-glass, the same materials are used as in crown-glass, the difference being in the manner of forming the sheet. When the metal is melted, the workman dips his tube into the pot, and when he has gathered a sufficient quantity of the liquid glass upon it, he places it in a horizontal position upon a hollowed block of wood. He turns the rod round in his hand, with the metal resting upon the hollowed block, which forms it into a solid cylindrical mass. Water is poured upon the block during this operation, to prevent the burning of the wood and the scratching of the glass. If the glass was only red hot, on coming in contact with the water, it would crack; but at the great heat at which it must be kept so as to be ductile, no injury takes place. When the metal is sufficiently formed and cooled, the workman blows into the tube until he perceives the diameter to be of the dimensions required, which depends upon the size of the sheet to be made. The bulb-shape body is again put into the furnace, and when softened, the workman swings it round his head, re-heats, and continues to swing it, until the cylindrical mass has attained what he thinks a sufficient length. He then fills it with air, at a slight pressure, by blowing down the blow-pipe, and closes up the hole with his thumb, so that none may escape; after which the end of the cylinder is again put into the furnace, and as it becomes soft, the air bursts from the end opposite to the tube, leaving an aperture. The cylinder is now turned round very quickly, which renders the ruptured end perfectly regular; and then, by applying cold iron to the end of the glass next the tube, a sudden contraction takes place, which separates the cylinder of glass from the iron tube. The different forms through which the workman makes the first gathering of metal pass until the perfect cylinder is formed and split, are seen in fig. 13. The cylinder thus formed is allowed to

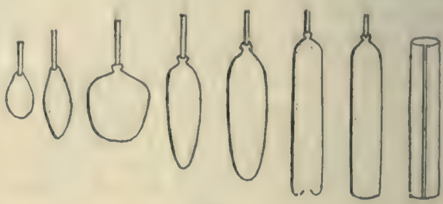


Fig. 13.

cool for about five seconds, and is then split up lengthwise by drawing a diamond along the inner side. The glass has next to be flattened, which is done by softening it in a furnace upon a smooth plate, where, as it begins to melt, it gradually opens, and is smoothed with a piece of charred wood. It is then carried to the annealing-furnace to be tempered, in the same manner as crown-glass. The method above described of making sheet or cylinder glass was introduced, in 1842, from Belgium by the Messrs Chance. These gentlemen have effected many improvements in the manufacture.

Sheet-glass may be made of any thickness, and possesses considerable advantages over crown-glass, from the greater size of sheets obtainable. For the Great Exhibition of 1851, cylinders were blown yielding sheets 49 by 30 inches, which were cut into panes 49 by 10. Of these, 300,000 in number, or 896,000 superficial feet, and 400 tons in weight, were made in a few weeks, and without disturbing the ordinary economy of the manufactory in which this large order was executed; in fact, the ordinary business under this immense strain was only retarded three weeks. The introduction of machinery for grinding and polishing by Mr James Chance, of Messrs Chance & Co. of Birmingham, effected quite a revolution in the trade in this country, and is characterised as one of the 'greatest improvements which has ever been introduced in the manufacture of glass.' By this means, large sheets are obtained, in appearance equal to plate-glass, at a much lower price. In Mr Chance's plan, each sheet of glass is laid upon a flat surface, covered with damp leather —'the sheet adhering completely to the leather, after having been pressed against it, producing in truth a vacuum, which maintains the whole sheet in a flat position. Two sheets having been placed in this manner, each on a retaining

or sucking surface, they are turned against the other in a horizontal position, sand and water being constantly supplied between them; and by means of the most ingenious machinery, the two surfaces rapidly rub one against the other in all directions, and are ground at the same time by the sand.' The other sides are then subjected to the same process. A very thin layer only of the surface is rubbed off, the sheet lying so perfectly flat.

Plate-glass.

The manufacture of plate-glass requires greater care than either of the two preceding kinds, and the process is different—plate-glass being moulded, and not blown, as is the case with other kinds of glass-ware. The materials, generally speaking, are the same, great purity, however, being always aimed at, especially in the sand: a small quantity of lime is added to the sand and soda, and the English makers use a small quantity of arsenic. In France, where the most perfect, but also most expensive plate-glass is produced, the makers use borax instead of arsenic: this renders the glass so soft, that, although it makes better mirrors, it is not so well suited for putting in windows.

For the melting of the materials, the pots used are the same as those used in the manufacture of crown and sheet glass; but in addition to these are other and similarly formed pots, called cisterns, differing only from the melting-pots in having a stout rib running around each one about its middle. When the glass is properly melted and scummed or *refined*, it is ladled out with a copper ladle into the *cistern*, which stands in the furnace beside the *pot*. The cisterns are suited in size to the sheets which are to be cast. The metal is left in the cistern for ten or twelve hours to fine, after which it is lifted out by means of an enormous pair of pincers, which are balanced on a fulcrum resting on wheels, so that the cistern is laid hold of, lifted out of the furnace, and wheeled to the casting-table. Then it is lifted by a crane, which places it over the casting-table—a beautifully smooth and polished plane of iron, 20 feet long, by 10 or more in width. Upon this the metal begins to flow rapidly in a glowing red-hot state. Two bars of polished iron of the thickness of the intended glass plate are laid one on each edge of the table, and a polished iron cylinder of considerable weight, and long enough to rest on the edge-bars, is lowered, and rolled along the bars: this spreads out the liquid metal over the table; the bars preventing it from running over the sides, and regulating its thickness. For a few seconds after the rolling is finished, the appearance of the sheet of glass is very beautiful: at a glowing red heat, it parts irregularly with its heat, and hence its surface, notwithstanding it has been rolled with a polished roller on a polished iron table, is a miniature sea covered with waves. This will be quite understood by any one who has seen rough plate-glass.

In a very short time, the sheet is sufficiently hardened to allow the operators to seize it on either side with hand-pincers, and pull it forward on to an endless band of wire-gauze, which is of equal width with the table. This band travels on rollers, and transfers the sheet of glass to the annealing oven, which is of immense length, as the sheets must lie flat in it, being too large to be tilted on edge, as in the crown and flint glass kilns. After a sufficient annealing, the plates are next polished.

The *polishing* is done chiefly by machinery. In the first process, the plate of glass is laid upon a low table, and is imbedded in cement, so as to leave only the upper surface exposed. Suspended over the table by long rods of iron are the rubbers, pieces of wood which rest on the surface of the glass. To the iron rods are attached crank arms, which are moved by steam-power, and make the rubbers move rapidly in circles over the surface of the glass, which is kept well supplied with fine sand and water. When all the irregularities are rubbed down, and the surface is perfectly level, the plate of glass is reversed, and the other side dressed in the same way. The next process is performed by women, who take large fragments of glass, and apply them with emery and water to the surface of the plate, and rub till the whole is polished, and all the sand-marks are removed. The final polishing is done by a series of mechanical rubbers, which are covered with leather, and supplied with *minium*, or red-lead, as the polishing material. These rubbers move with great rapidity backwards and forwards, upon a large table, upon which the plate is laid, and they are sufficiently numerous to act upon every portion of the plate, and give it the beautiful lustrous polish which makes this kind of glass so valuable.

Plate and sheet glass are both made into mirrors; the latter only for those of a small size. The ordinary plan is, to take tinfoil and lay it over the surface of the glass, which is for the purpose placed on a very strong table, with a raised edge running round it, and with green baize, or other cloth, between it and the glass. Quicksilver is then poured over the tinfoil, with which it forms an amalgam, and the whole is covered over with smooth boards, upon which very heavy weights are placed, which press the amalgam, and squeeze out any free mercury. After a sufficient time, the weights are removed, and the mirror is finished. Several other methods have been from time to time employed, all consisting chiefly in precipitating silver from the solutions of its salts upon the surface of the glass, but hitherto they have not supplanted the old method, which is that chiefly employed.

Flint-glass.

Flint-glass, or crystal, is composed of fine white sand—which is calcined, sifted, and washed for the purpose—red-lead, or litharge, and refined pearl-ash. It was formerly made of calcined flint, but the finest Lynn sand has been found to produce a clearer glass, and is therefore preferred.

A flint-glass furnace varies little from those described for other kinds of glass, except that it is round in the top. The pots in which the glass is melted have their tops arched over, that no dust may fall in, with a hole at the side near the top, for the insertion of the tube (fig. 11). When the glass is sufficiently melted, the tube is inserted, and a quantity lifted out upon its point, in the same manner as for crown-glass. After being rolled upon the marver, the glass is blown out to a globe-shape, when the punty-rod is attached, and by means of an instrument resembling a pair

of sugar-tongs, the glass is moulded to the form required. The shapes into which flint-glass is manufactured are so numerous, that it would be almost impossible to describe them all. The operations are extremely simple and beautiful, and are performed with a rapidity which is truly astonishing. The workman is furnished with a pair of compasses and a graduated scale, to measure the articles which he is making, by which they are kept of a uniform size. When finished, the articles are all weighed, to see that the right quantity of glass has been used in their manufacture, and after this they are put into the annealing-furnace.

Optical glasses are made from fine flint-glass. The utmost care is necessary to keep the metal entirely free from waves, otherwise the glasses will be useless. An *achromatic* object-glass for a telescope or microscope—that is, an object-glass which does not produce coloured fringes around the edge of the image—known as chromatic aberration—must consist of three lenses made of different kinds of glass, differing in the proportion which their refractive bears to their dispersive power. Flint-glass and crown-glass are well adapted for being formed into such a compound lens, the dispersive power of the former being nearly double that of the latter, while the mean refractive powers of the two kinds are nearly the same.

Bottle-glass.

Bottle-glass is composed of the coarsest materials, generally soap-boilers' waste and sand. The furnaces and pots for preparing bottle-glass are similar to those used for crown-glass; and the raw materials are treated much in the same way. As the mixture always contains a very small relative proportion of the alkaline ingredient, its vitrifaction requires a high temperature; but it is usually complete in eighteen or twenty hours. After the undissolved matter has subsided, the *sandiver*, or 'scum,' which rises being skimmed off, and the glass cooled down to blowing consistency, the mass may be worked up into bottles. For this purpose, the workman introduces his tube, and when sufficient is gathered upon the end, he rolls the glass upon a stone, blowing into it at the same time. When sufficiently distended, he gives it the bottle form by turning it rapidly round, and shaping it with a wooden or iron tool. But bottles are now usually made by the moulding process, which is begun in the same way by the workman, who gathers the *metal* on his blow-pipe, and *mavers* it on the stone, as before mentioned. He then puts the metal into a brass or iron mould of the shape of the bottle to be made, and blows through the tube until it comes to the desired form. This mould is so contrived as to open down the middle by means of a spring which the blower works with his foot. The mould is open when he puts in the metal at first; it is then immediately closed, and opened again when the bottle is formed, which is handed over to the finisher. The finisher detaches the tube from the mouth of the bottle, and fixes the punty-rod to the bottom. He then warms the bottle at the furnace, and takes out a small quantity of metal, which is turned round the upper part of the neck, and forms the rim usually seen on bottles. The finisher next employs a pair of shears to give the right shape to the neck: on one of the blades of the shears is a piece of brass resembling a cork, by which the inside of the neck is formed. The bottles thus finished are sent to the annealing-arch, which is kept a little below melting-heat until full, when the fire is allowed to die out.

Cutting—Grinding—Etching.

The instrument universally employed in *cutting* window-glass is the diamond, which is set in a metal socket, attached to a wooden handle for this purpose. The cutting point of the diamond must be a natural one; artificial points, as well as those produced by breaking the diamond, only scratch the glass, without producing the deep cut which is necessary.

What is called glass-cutting, or *grinding*, is a separate trade from blowing in all glass-manufactories. The cutting-wheel is driven by means of a belt proceeding from a large drum attached to an engine or other moving power. Above the cutting-wheel is a conical box, from which wet sand drops upon it, while another is placed below, to receive the sand as it falls from the wheel. The wheels used are three in number: the first is made of cast-iron, by which the rough glass is ground; the second, of Yorkshire stone, by which the vessel is smoothed; and the third, of willow-wood, by which the final polish is communicated. For this last purpose, the wooden wheel is dressed with rotten-stone or pumice-stone; and for imparting the highest degree of polish, putty-powder is used. These wheels are of various forms, according to the shape of the vessel to be cut. They may be broad or narrow, flat-edged, two-edged, concave, convex, &c. The cutter holds the glass to the wheel while it is revolving, and the most beautiful and regular figures are engraved in this manner with astonishing rapidity. Imitations of cut-glass vessels are made by blowing the soft glass into a polished metallic mould, the form of which it acquires with as much faithfulness as wax.

As stated under CHEMISTRY, hydrofluoric acid acts energetically on glass, and is employed for the purpose of *etching* on this material. 'The art,' says Parnell, 'may be practised on all kinds of glass, but the most proper description is good crown-glass. The facts on which the art is founded are, that glass becomes powerfully corroded by exposure to the acid in question, and that certain parts of the glass may be easily protected by wax, or other kinds of varnish, on which the acid exerts no action, except at a high temperature.' A variety of processes are now in use for decorating the surfaces of glass-ware; space prevents us, however, from noticing any of these; we refer the reader, therefore, to other and larger works, for a description of them.

Staining—Colouring—Enamelling.

The art of staining or colouring glass is believed to be coeval with the discovery of the article itself. It is certain that it was known in Egypt several thousand years since, and tradition gives the honour of the discovery to an Egyptian king. The art of combining colours so as to produce pictures is of more recent date. The early specimens of stained glass exhibit a number of different pieces of various colours, joined together like

mosaic-work, so as to bring out the representation desired. The discovery of this art is ascribed to a painter in Marseilles, who went to Rome during the pontificate of Julius II. It was afterwards greatly improved by the celebrated Albert Dürer and Lucas of Leyden.

All the pigments used in painting on or staining glass are oxides of metals—as gold, silver, cobalt, manganese, &c.—which, after being laid on, are subjected to a strong heat, until they penetrate into the body of the glass, or become fixed on its surface, and thus give out their fullest brilliancy and transparency. The colours that are meant to penetrate into the glass for the purpose of staining it, are wholly transparent, while those which are merely fixed upon the surface are only semi-transparent. Any colour or tint can be communicated to the glass in this way, and the art is at present practised with great success. The description of glass best adapted for painting upon or staining, is the finest crown or window glass.

But coloured glass for windows is of two kinds, called *pot-metal* and *flashed*. The first is glass in which the colour is mixed in the melting-pot from which it is taken, blown, and formed into sheets either as crown or sheet glass. Flashed glass is prepared by first dipping the blow-pipe into a pot of ordinary colourless glass *metal*, and having gathered a proper bulb, it is dipped into a pot of coloured *metal*, so as to be thoroughly coated with it. It is then blown and formed into sheets as before, and is found to have a pretty equal quantity of each kind equally spread, so that it is in fact a double sheet of glass. This admits of many colours being used which as *pot-metal* would be too dense, and also of various pretty methods of ornamentation; for, if any portion of the coloured side be ground or etched off, we get a mixture of plain and coloured material, which, in the hands of skilled workmen, may be rendered very effective.

'The substances employed'—we quote from Parnell's *Applied Chemistry*—'for rendering colourless and some coloured glasses more or less opaque, like enamel, are phosphate of lime, fluor-spar, arsenious acid, peroxide of tin, phosphate of lead, and phosphate of antimony. Phosphate of lime, which is the only one of these materials commonly employed at present, with the exception of fluor-spar, is introduced in the form of finely powdered calcined bones, to the amount of one-twentieth to one-thirtieth of the weight of the glass. A very beautiful opaline crystal is obtained in this way.'

PASTES—ARTIFICIAL GEMS.

In gem-sculpture, *paste* is the term for a preparation of glass, calcined crystal, oxide of lead, and other ingredients for imitating gems. This art appears to have been well known to the ancients, and after being lost, was restored, at the end of the fifteenth century, by a Milanese painter. The general base of artificial gems is a vitreous compound known as the 'Mayence base' or Strass (from the name of its inventor). It is prepared, according to Fontanieu, in the following manner: 8 ounces of pure rock-crystal, or flint, in powder, mixed with 24 ounces of salt of tartar, are to be baked, and left to cool. The mixture is to be afterwards poured into a basin of hot water, and treated with dilute nitric acid till it ceases to effervesce; and then the frett is to be washed till the water comes off tasteless. This is to be dried, and mixed with 12 ounces of fine white-lead, and the mixture is to be levigated and elutriated with a little distilled water. An ounce of calcined borax being added to about 12 ounces of the preceding mixture in a dry state, the whole is to be rubbed together in a porcelain mortar, melted in a clean crucible, and poured out into cold water. This vitreous matter must be dried, and melted a second and a third time, always in a new crucible, and after each melting, poured into cold water, as at first—taking care to separate the lead that may be revived. To the third frett, ground to powder, 5 drachms of nitre are to be added; and the mixture being melted for the last time, a mass of crystal will be found in the crucible of a beautiful lustre.

A base being thus prepared, the peculiar colours are obtained from the metallic oxides, which, in proper proportions, under the hands of an experienced manipulator, are said to yield imitations so like the natural gems, that none but lapidaries or mineralogists could detect the deception.

The ancient Greeks were very skilful in making *pastes* by joining portions of white or tinted opaque glass to glass variously coloured. They imitated the onyx, and used the imitation for cutting cameos, some of which are remarkable for their great beauty. The celebrated Portland Vase was made in a somewhat similar manner.

CEMENTS—ARTIFICIAL STONES.

Under this section we rank those compositions generally known as cements, mortars, concretes, plasters, and stuccoes.

The *mortar* or cement employed to unite stones and bricks into a compact mass in building, is composed of quicklime, sand, and water. Quicklime is procured by roasting or calcining limestone in kilns, into which moderate-sized fragments of the rock are placed in alternate layers with coal or turf. By this process, water and carbonic acid are expelled, and the limestone converted into what is called *shell* or unslaked lime. This is then reduced to powdery quicklime by *slaking*—that is, by pouring as much water upon it as will suffice to destroy the cohesion of the particles. When intended for mortar, the quicklime should be immediately incorporated with sand, additional water being mixed in so as to bring it to the consistency required when used.

When common mortar is made so fluid with water as to be poured on a course of brick or stone work, it is known by the name of *grout*. Where great strength and durability are required, the practice of grouting the hearting or packing of the walls is usually adopted; as by this means the interstices are filled, and the whole rendered, by the hardening of the lime, a solid compact mass. Foundation *concretes* are generally formed of small angular stones well packed and grouted. Such concretes are proof against all moisture and decay, and, on indifferent subsoils, form more resistant foundations than isolated blocks of stone, however large and heavy.

Hydraulic or *water cements* are those which have the property of hardening under water, and of consolidating almost immediately on being

mixed. Common mortar, although it stands the effect of water very well when perfectly dry, yet occupies a considerable time in becoming so, and dissolves or crumbles away if laid under water before it has had time to harden.

The general term Roman has been applied to that class of hydraulic cements made from the natural argillaceous limestones found in Britain, and especially to that formed by burning the nodules of septaria found at Harwich ; these contain from 20 to 25 per cent. of clay, without which they would be useless for hydraulic cements, and would not possess the property of hardening in water.

Several artificial hydraulic cements are now in use, the best known of which we may here shortly describe. *Portland Cement:* This important cement is 'made from carbonate of lime, mixed in definite proportions with the argillaceous deposit of some rivers running over clay and chalk, together under water, and afterwards dried and burned. The strength of the composition is very remarkable, being nearly four times as great as that of any other kind. Portland cement makes an admirable and most powerful concrete, the proportion of cement required being only a tenth or a twelfth part.' Natural substances are also frequently used for the formation of hydraulic cement. Of these, *puzzolana* is the most notable. This was used by the Romans in building the foundations of their quays, artificial islands, &c. It is chiefly obtained from Puteoli, or Puzzuoli, near Naples, whence its name. This earth is a light, porous, friable mineral, various in colour, and evidently of volcanic origin ; mineralogically, it may be designated a calcined ferruginous clay. When reduced to powder by beating and sifting, and thoroughly mixed with lime, either with or without sand, it forms a mass of great tenacity, which in a short time cements to a stony hardness, not only in the air, but likewise when wholly immersed in water. *Dutch trass* is a somewhat similar substance, which used formerly to be imported from Holland, where it is extensively used in hydraulic works. It is made from a light vesicular lava found near Andernach, on the Rhine.

The *Selinitic* cement of Major-general Scott is the newest introduction, and is rapidly coming into favour. It contains gypsum, but the mode of its manufacture is not made known.

Plaster, or the material which is used to spread smoothly over walls, is of various kinds. That which is applied to inner walls or partitions, is formed of certain proportions of slaked lime, fine sand, and water, with mixture of cow-hair, to assist in giving cohesion. The best plaster is now prepared by the pug-mill, by which the ingredients are more thoroughly incorporated than by the old process of hand-beating. Spanish white, ochre, and other colouring matters are added when any peculiar tint is wanted ; but we may here remark, that the most durable of all plasters, and that which answers best even for fresco-painting, is composed simply of well-slaked lime and sifted river-sand. The surface of plaster is now seldom finished with a view to permanent exposure—whitewashing, sizing in colours, oil-painting, and, above all, papering, being the prevalent fashions of the day.

Stucco is the name ordinarily given to plaster of Paris, which is gypsum reduced to a powder by heating and grinding; but the term *stucco* is further extended to embrace all those compositions with which walls are coated or ornamented, in imitation of stone. Gypsum is properly a sulphate of lime ; and, like all other varieties of lime, it has a strong power of absorbing water. The practice is, to put the masses into a heated oven, and when duly baked, to take them out, and grind them to powder in a mill. This powder, when sifted, is a beautiful white substance, resembling flour. A quantity of powder being put in a vessel, water is poured upon it, and immediately the stuff thickens in a surprising manner, and soon becomes a hardened mass. While still thickening or setting, it is poured into a mould for any required shape ; or it may be applied along with a little lime as a fine plaster, which it is desirable should dry speedily. It is used largely for all kinds of casts from pieces of sculpture, mouldings for cornices, &c. There are none of the artificial stuccoes which yield so sharp or delicate a cast ; but most of them excel it in hardness and durability. Gypsum, or sulphate of lime, is the basis of all the cements known as Keene's, Martin's, Parian, &c. In these, the 'plaster in the state of fine powder is thrown into a vessel containing a saturated solution of alum, sulphate of potash, or borax. After soaking for some hours, it is removed, and air-dried, and subsequently rebaked at a brownish red heat.' It is finally reduced to a fine powder, which, when required for use, is mixed with a solution of alum. 'When borax is used, the plaster is called *Parian*, but where sulphate of potash is employed, it forms Keene's Cement. The kind called Martin's Cement is made with pearl-ash as well as alum, and is baked at a much higher heat than the rest.' All these cements are greatly used, and are particularly valuable 'when a hard durable substance is required, not affected by damp, and perfectly safe from the attacks of vermin.' They are worked with great facility.

Scagliola is the Italian term for a composition intended to represent various marbles, porphyries, serpentines, &c. It is composed of fine plaster of Paris, with colouring matters, mixed with glue or isinglass, and is sometimes studded with chips of alabaster, &c. to imitate verd-antique, &c. It is laid on like common stucco, moulded into the desired forms, and allowed to set. When thoroughly set, it is smoothed with pumice-stone, and washed ; then polished with tripoli and charcoal ; next with tripoli and oil ; and finally with pure oil, laid on with cotton wool. The result is a surface of unusual richness ; but from the nature of the ingredients, it is only fitted for internal decoration, and even then requires to be kept dry.

Bituminous Cement.—This is best known by the name of Asphalt. Asphalt, or asphaltum, is a bituminous mineral, allied in its nature to pitch, and is found in the form of rocky masses in different parts of the world. For pavement, it must be mixed with sifted gravel, pounded iron slag, or river-sand, which gives it more stability, and a degree of roughness that is not unnecessary. The composition is prepared in portable boilers or caldrons, and spread while hot on a properly prepared bed ; and being rendered smooth on the surface, it offers an exceedingly agreeable resistance to the foot, being not so hard as stone, nor so soft as a mud pathway.

Mastic is properly a resinous substance obtained from incisions made in the branches of the *Pistacia lentiscus*, and received its European name from being chewed or used as a *masticatory* by women in Turkey, for the purpose of cleansing the teeth, and imparting an agreeable odour to the breath. But the term *mastic* is also applied—not very appropriately—to certain cements which are used for architectural purposes, and especially for setting the tesseræ of mosaics. It is composed of about 93 parts of calcined clay, mixed with 7 parts of litharge, and worked up into a paste with linseed-oil.

Artificial Stone.—The soluble silicate of potash or soda, termed 'water-glass,' has been for some time used as a binding cement, by which sand and a little lime have been formed into artificial stone, almost equalling in appearance and strength some of the best natural sandstones. M. Kuhlmann of Lille, and Mr F. Ransome of Ipswich, have been the most successful workers in this field. Mr Ransome by his first method fired the above mixture in a kiln; but afterwards he made by another plan an artificial stone with sand, fragments of granite, chalk, or other mineral, forming an intimate mixture of one or more of these with water-glass in a pug-mill, and then moulding the substance, while soft, into any required form. On the addition of a solution of chloride of calcium, an insoluble silicate of lime is formed, which binds the whole into a firm mass. A strong kind of artificial stone is formed of Portland Cement, mixed with chips of stone or gravel. This material was used in the construction of the Suez Canal, and the breakwater erected at Aberdeen has been constructed of it. There is another imitation of stone, made chiefly of sand and lime, from which what are called 'stone-bricks' are now manufactured. Slag from iron furnaces is yet another material sometimes used as a substitute for stone in the shape of rectangular blocks, but being of very irregular texture and composition, it cannot be relied on for durability.

Moulding compositions for making architectural ornaments in relief are now extremely common, and in most instances well fitted for the object in view. The substances chiefly used for this purpose are carton-pierre, papier-mâché, stamped leather, &c. Carton-pierre is now very often used. From its lightness, durability, and ease of application, it is peculiarly adapted for architectural decoration. It is composed of 'the pulp of paper mixed with whiting and glue. This preparation is pressed into plaster piece-moulds, backed with paper, and then, when sufficiently set, removed to a drying-room to harden.' The drying is effected in a few hours, which is a great advantage. 'Bois durci' is now much used for ornamental mouldings. It is a composition in which the principal ingredient is charred sawdust, and forms a remarkably good imitation of ebony.

DECORATIVE DESIGN AS APPLIED TO FICTILE MANUFACTURES.

Utility is the primary design of all manufactured articles; this, therefore, should never be lost sight of, but the ornament should always be subservient to the main design. Ornament has therefore been defined as the 'decoration of a thing constructed.' Thus a jug is designed to hold a fluid, and to allow of it being taken from and put into it with great ease; but if the form, or the ornament added to the form, be of such a kind that the jug cannot be used as a jug, it is merely an ornament having the shape of a jug. When we find articles, such as vases, having forms or ornament given to them entirely inconsistent with their known uses, we at once trace a want of truth in the design. From these considerations is derived the canon or rule, that 'ornament should arise out of, and be subservient to construction.' It is in this sense that architecture has been defined as 'decorated construction.'

Ornament is derived from three sources: from natural forms, from the conventional ideas, and from simple geometrical figures. These, of course, are all resolvable into one source—that of nature; but it is convenient to arrange them as above. There are two great schools of ornament. One school holds that natural forms closely imitated are the best suited to the decoration of works of utility or art—that, in the words of one of its most eloquent followers, 'all the true nobleness of art had come from people loving nature in some way or the other, expressing their sentiments about nature; and exactly in proportion as the reference to nature had become *more direct*, the art became nobler.' The other school hold widely different views. Thus one of its ablest exponents gives the following: 'Flowers or other natural objects should not be used as ornament, but *conventional* representations founded upon them, sufficiently suggestive to convey the intended image to the mind, without destroying the unity of the object they are employed to decorate.' The government 'Department of Science and Art' takes this view, for one of the principles of decorative art published under its sanction is the following: 'True ornament does not consist in the mere imitation of natural objects, but rather in the adaptation of their peculiar beauties of form or colour to decorative purposes, controlled by the nature of the material to be decorated, the laws of art, and necessities of manufacture.' To take up space in investigating which of the two schools, the 'natural' or the 'conventional,' is the correct one, would serve no useful end; at the same time, we may say that the middle course seems the best. There are certain natural forms which, applied to certain purposes, would be best adapted the more closely they were imitated; while for other purposes, a conventionalising would be in better taste. Everything depends upon the material to be ornamented, the way in which this material is to be manufactured, and the uses to which the manufactured article is to be put. It is manifestly erroneous to apply a close imitation of a natural form to an article the use of which conveys an idea altogether opposed to that which the natural form suggests. Thus, when we see a gas jet issuing from a water-lily, or water-plants spread over the surface of a carpet, we are at once struck with the obvious inconsistency. But referring the reader to special works on design for further information on the points we have indicated, we shall proceed to offer a few remarks on the application of decorative design to the various fictile manufactures which form the subject of the present paper. Taking these in their order as we discussed them, our remarks will first have

reference to ceramic manufactures—pottery and porcelain.

The first point to be attended to is utility. To give a form, for instance, to a vessel which prevents its being cleaned, or to put a handle to it in such a way as to prevent it being lifted, is a manifest absurdity; such absurdities, nevertheless, have been often perpetrated. The ornament should also be subservient to the purpose for which the vessel is used. Thus, where it is likely to be in frequent use, all ornament should be avoided which will render it difficult to be cleansed, or afford facilities for dust and dirt harbouring. The nature of the material will also dictate rules for its ornamentation. Thus brittleness will prevent ornament in high relief from being used: 'All projecting parts should have careful consideration, to render them as little liable to injury as is consistent with their purpose.' Again, the peculiar characteristics of the material should be preserved and brought out; hence the absurdity of applying a surface-colour which gives the idea of another material, as the metallic lustre we see often in common vessels, or one conveying the idea that the material is marble. 'Landscapes and pictures are almost always,' says Mr Redgrave, 'out of place in pottery; and it certainly is objectionable to cover the centres of plates and dishes with pictures and views, not only because it hides the surface which it has been before said it is desirable to retain, but because utility would be better served by the absence of any decoration on the part which receives the viands, to satisfy that sense of cleanliness only to be obtained by the white unchanged surface of the material. . . . In the application of colour to porcelain and earthenware, the surface should never be wholly or indeed largely covered; the material has a purity that should be decorated, not obscured.'

In designing articles made of glass, due attention should be paid to the peculiar nature of the substance. Its transparency; its purity of surface, which, if tarnished by use, is easily restored by cleaning; its brittleness, which prevents its use for merely constructive purposes, as, for instance, where a weight is to be supported—all these should be considered in the design. The use to which the vessel is to be put, must also be considered. Our remarks on this point, in speaking of pottery articles, are applicable here as well. A great deal of bad taste is often displayed in ornamented glass. Its transparency is frequently marred by a redundancy of obscuration, effected by grinding, or it is rendered opaque by dead colouring, or imitations of other materials, as opal or metal. Its purity of surface is destroyed by an excess in cutting; and its absence of all constructive qualities forgot in its frequent adaptation to architectural decoration. On this latter point, Mr Wallis very justly remarks: 'The inappropriateness of architectural details, the value of which as ornaments consists in their outline, and the effects resulting from a play of light and shadow, being applied *to* and *in* a material in which the effects are obtained by a light in transition, is at once obvious, if that very simple but much-neglected question as to the nature of the material to be used is even fairly asked and honourably answered.'

In the application of glass to *mere ornament*—meaning by this, articles not of everyday utility, as chimney-piece and drawing-room decorations—the peculiarities of the material are still more frequently ignored. Thus, colouring in rich tints, overlaying the surface with gilding, imitation of opal, papier-mâché, and porcelain, completely hide the peculiarities, and attach ideas to the material altogether wanting in truth.

As regards the form of the articles, that is the best which gives the idea of lightness and elegance. 'In all cases, elegance of form should be the first consideration, to which cutting, gilding, or engraving should be entirely subordinate.' The ornament, says another authority, should be 'so arranged as to enhance by its lines the symmetry of the original form, and assist its constructive strength.'

In the department of stained-glass decoration, much might be said, did space admit. There are two schools or modes of treatment—one, the oldest, in which the subjects were not treated pictorially, but composed with 'extreme monumental simplicity,' severe outline, and thoroughly flat treatment; the other, the modern or continental school, in which all the characteristics of a picture, careful drawing and perspective effects, are attempted to be given. Each of these schools has its able advocates. Mr Ruskin's dictum is as follows: It should 'always be remembered by the workman, that the use of a window was to let in light, and that the virtue of the glass in a window was to be transparent; and that all art which tried to represent it as opaque, as a picture instead of a window, was mistaken and absurd.'

Of the moulding compositions we have noticed, papier-mâché is the most generally used. As regards the received ornamentation of this material, Mr Redgrave says it is 'the most gaudily decorated of all manufactures, and seems quite beyond the pale of any just principles of ornament. . . . At present, it is a mass of barbarous splendour that offends the eye, and quarrels with every kind of manufacture with which it comes in contact.'

In drawing up the remarks in this and the following number on decorative design, as applied to manufactures, we have been much indebted, amongst other authorities, to Mr Redgrave, R.A. who appended to the Jury Report of the Great Exhibition, a Report on Design, replete with instruction and suggestions of a highly valuable nature.

TEXTILE MANUFACTURES.

TEXTILE manufactures, strictly speaking, are those which are woven, and embrace fabrics made either of animal or vegetable fibres; but the name is now applied to several other products of these materials, in which the fibres are so arranged as to give to the whole an expanded surface in a thin layer, so that they can be used in a similar manner to those actually woven. Thus, we now include the processes of felting, netting, knitting, lace-making, plaiting, and even paper-making, under the general term of Textile Manufactures.

LINEN.

Of the various textile manufactures, strictly so called, that of linen is the most ancient. In the oldest records of history, sacred and profane, mention is made of it; and the notices given of the fineness of its texture, are evidence of the degree of skill then displayed in its manufacture. The word *linen* is derived from the old name of the plant now called flax, which is preserved in *line*-seed, or *lin*-seed. Linen is cloth made of *lint* (Lat. *linteum*), which is the fibrous bark of the flax plant (*Linum usitatissimum*).

The plant is an annual, of very slender growth, and usually only slightly branched at the top of the stem, which grows from one foot and a half to two and a half feet in height, rarely higher. The flowers are of a very delicate light blue colour, and the leaves small, as represented in the following woodcut, which gives correctly all parts of the

Fig. 1.—Common Flax (*Linum usitatissimum*).

plant, except the long thin and almost leafless stem. It is grown in most parts of the world, but requires a cool temperature for the perfection of its fibre, so that in India and other warm countries, it is grown chiefly for its seed, which is of great value for the oil it yields. The finest in the world is produced in Belgium and Holland; the largest quantities are yielded by the provinces of Russia, which is said to produce 160,000 tons. Considerable quantities are also received from Egypt. That from Holland and Belgium is sufficiently fine to yield thread for making lace. Ireland yields about 40,000 tons of good quality.

Great care is required in the cultivation of flax, which requires a deep, rich, well-drained soil. It is sown broad-cast, and, especially if required to produce the finest or thinnest quality, it is sown thickly, so as to become etiolated, or drawn up. Sown in April in our climate, this crop is usually ready for gathering about the end of July or beginning of August.

When the seeds are beginning to change from a green to a pale brown, is the best time for pulling the flax. Where the crop grows of different lengths, these lengths should be pulled and kept separately, uniformity in this respect being of great value in the after processes.

The pulling is carefully done by hand, and the flax is laid in rows to dry, after which it is collected and tied into bundles, and taken to a covered place to have the seed-pods removed by the process called *rippling*, which consists in pulling the stalks through a series of iron teeth eighteen inches long, placed within a distance of half an inch of each other. These are fastened in a block of wood, which is placed at the end of a plank or long stool on which the operator sits. The rippling deprives the flax of its seed-capsules, which, when thrashed, yield linseed, valuable as affording oil, and oil-cake, much used for feeding cattle.

The thin stem of the flax plant consists of three distinct portions—the central, or hard pithy portion, technically called the *shove* or *boon;* over which are laid the fibres, called the *bast* or *harl;* and covering these, the *cuticle*, or outer skin. Neither of these parts is easily separated from the other, as they are in a manner cemented together by a gummy matter, which, fortunately, is more easily destroyed by decomposition than the other portions, except the cuticle, which is easily rotted by damp. This is effected by steeping the bundles in water till the cuticle and gummy matter begin to rot, in which state they are readily separated from the fibre. The operation is called *retting*, or rotting, and requires to be managed with great care, as, by continuing it too long, decomposition might extend to the fibre, and render it useless; while by discontinuing it too soon, the separation could not be effected with sufficient ease. After being sufficiently steeped, the flax is spread out on the grass, to rectify any defect in the retting, and ultimately to dry it for the breaking. In some districts, it is the practice to conduct the retting entirely on the grass—a process known as dew-retting, in contradistinction to water-retting.

To avoid the delays and uncertainty dependent upon the old processes of retting or watering, plans have been recently introduced, bringing the operation more under control, like the other processes of our manufactures.

Prepared by either of the plans, the flax is now ready to be freed completely of its woody particles. This is effected by *scutching*. Previous to this, however, the flax is passed through a *brake* or revolving rollers, in order thoroughly to crush the boon. The brake, worked by manual labour, consists of a frame, in the upper side of which are a number of grooves; a movable piece is hinged at one end, and provided with a similar grooved piece on its lower side, but so placed that the projections pass into the hollows of the lower. The flax, placed between these, and struck by bringing down the hinged part, is broken, but the fibre remains uninjured.

In the flax-breaking machine, the flax is passed through a series of horizontal fluted rollers; the flutes do not touch, thus preserving the fibre while breaking the boon. In Plummer's machine, five rollers are used, and the pressure on the flax is regulated by weights suspended to the axles of the rollers. Fig. 2 is a diagram illustrative of this machine; the flax to be broken is laid upon the table *f*, and passed between the rollers *a*, *b*; from these it is led by the curved plate *hh*, to the rollers *b*, *c*; from thence to *d*, *e*, and finally placed on the table *g*. In continental countries, scutching is almost invariably performed by hand, the flax being held in a groove made in an upright stand, and struck by a flat blade. Machine-scutching is much more certain and expeditious than hand-scutching, and is, in consequence, fast superseding it in this country. After passing through the breaking-machine, the flax is subjected to the action of a series of knives, *b*, *b*, attached to the arms of a vertical wheel, *a*, fig. 3; these knives strike the flax in the direction of its length. A side-view of the arms and knives is shewn at *c*, *c*, fig. 3. The process is gone through

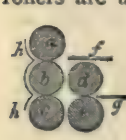


Fig. 2.

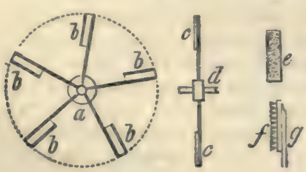


Fig. 3.

three times before the flax is ready for the market. Although machine-scutching is expeditious, it is not capable of that pliant adaptation to the varying nature of the flax to be operated upon, which is obtained in hand-scutching. The effect of machine-scutching is to produce fineness by reducing and impairing, rather than sustaining, the character of the fibre—namely, the length and fineness of its 'staple' or fibre.

The diagram to the right of fig. 3 shews part of the disk, *g*, to one side of which brushes (of which one is seen at *f*) are attached: *e* is a front-view of the brush *f*.

After being scutched, the flax is made up into *stricks*, or small bundles, and taken to the next process, which is the first of what are strictly called the 'manufacturing operations.' The bundles are usually composed of fibres some eighteen to thirty inches long; the part nearest the ends is of least, that nearest the centre of the fibre of the highest, value. To obtain the most valuable portion of each strick, it is separated into three, sometimes four parts, by means of a machine, of which fig. 4 is an illustrative diagram. In the centre of the framing, a wheel, *aa*, is supported on a shaft or axis; the periphery of this is furnished with a series of projecting or cutting edges of an elliptical form. On each side of this cutting-wheel, two pair of grooved rollers, *bb*, *cc*, revolve. An end-view is given to the right of the cut, in which only the set of rollers at one side, *b*, *b*, are visible. The stricks are held stretched between the adjacent pairs of rollers, *b*, *b*; and the revolution of the rollers advances the flax sidewise against the cutting edges of the wheel, so that it is divided into two lengths, the one, however, being shorter than the other. The longer of the two parts is passed through the machine a second time, and thus each strick is divided into three lengths, of which the middle portion is more valuable than the two end portions. The three lengths thus obtained are laid on separate heaps, to be ready for the succeeding process of *hackling*.

Fig. 4.

The object of this is thoroughly to clean the fibres, and to parallelise them, the cleaned portion being termed *line*, the refuse *tow*, which last is used for coarse sacking, &c. Hackling, as performed by hand, is as follows: The hackle is a strong comb, composed of several rows of steel teeth, four or five inches in length, fixed upright in a block of wood as a base, and made fast to a bench, fig. 5. The workman, taking a handful of scutched flax, strikes it against the pointed summits of the teeth, and draws it through—repeating the process till the requisite fineness is obtained. Coarser and wider-toothed hackles are first used, and then others progressively closer, as the fibres become finer by separation.

Fig. 5.

The process, however, is now almost universally effected by machinery, the nature and operation of which may be briefly described. The hackling-points are arranged in bands, or alternate rows, *a*, *a*, fig. 6, round the circumference of a cylinder, *bb*; the rows of points are of different finenesses—the row at one end being coarsest, the next finer, and so on. The flax to be operated upon is suspended above the cylinder by means of a holder, *c*. The process is threefold—first, as the end of the strick of flax depending from the holder is required to be hackled less than the middle portion, the strick is made to rise from, and approach to, the hackling-points; as the strick falls, the hackling-points pass through the ends, obtaining a deeper hold the lower the strick descends, and the thicker portion comes in contact with the teeth; and *vice versâ*. The strick is made to rise and fall as thus described, by placing the holder which carries it upon a *table*, *dd*, which, by means of a cam-movement, is made to rise and fall as desired. The second movement desiderated is the pushing of the holders with their stricks along the table, to put the flax successively in contact with the rows of hackle-teeth of different gradations of fineness. This is effected in a variety of ways by ingenious

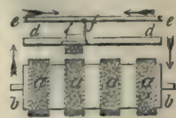


Fig. 6.

machinery, which is constantly undergoing improvement. One method adopted is illustrated in fig. 6. The rod *ee* has an alternate lateral movement, as shewn by the arrows; fingers, one of which is shewn at *f*, are jointed to the under side of this, and hang downwards. They are prevented from moving in one direction by means of a snag or projecting part attached to *ee*. As the rod *ee* moves in one direction, the fingers give way, and slide over the top surface of the holders; but on its moving in the other direction, the fingers come in contact with the ends of the holder, and being prevented from moving by the snag above mentioned, they press against the holders, and move them along the table *dd*. The third movement required is to place the flax so that both sides of the strick shall be subjected to the hackles. As the hackles revolve always in one direction, it is necessary to turn the stricks after passing through the machine, before sending them a second time through. This, in many machines, is effected by hand; but in Carmichael's the strick is made to give a semi-revolution by ingenious mechanism; while in Plummer's patent machine, both sides of the strick are hackled at once, by allowing the strick to be suspended from the holder *c*, between two revolving cylinders, *a*, *b*, fig. 7, in the peripheries of which are fixed a series of brushes.

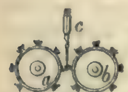


Fig. 7.

The flax is next passed through the 'spreading-machine'—the object of which is to bring the fibres into the condition of a long, narrow band, of uniform thickness. As the stricks from the hackling-machine are of different thickness, they are spread upon a table, *c*, fig. 8, the thin part of one being placed against the thick part of another. The sheet of flax thus prepared is passed between a pair of rollers, *a*, *b*, on to a series of upright hackle-teeth, represented by the line *h*, which have a progressive movement from the front to the back of the machine; these teeth still further comb and parallelise the fibres as they are moved onwards to a second pair of rollers, *d*, *e*, which, revolving faster than the first, *draw* out or lengthen them. The thin sheets of flax from the different rollers are passed in fours through slits made in the back plate of the machine, and being united into one, are finally passed between a pair of rollers, *f*, *g*, and delivered to a tin can. The subsequent processes of *doubling*, *drawing*, and *spinning* are all nearly the same as in the cotton manufacture, afterwards described in this paper. The only difference is, that in spinning flax the slivers are previously passed through hot water of 120°, and are worked in a moist and warm atmosphere; this is necessary to soften the gummy matter of the fibre, and utilise its adhesiveness in making the twist of the fibres more permanent. Weaving being a process common to all the textile fabrics, of the nature of cloth, will be described when speaking of the woollen manufacture.

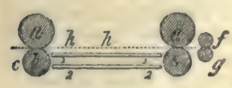


Fig. 8.

The *tow*, which is the broken, coarse, and irregular fibres removed from the *line* by hackling, is now extensively used in the manufacture of inferior carpets and other fabrics, for which purpose it is carded and spun into yarn the same as wool.

In the majority of flax-mills, the operations cease with the spinning of the fibres into the yarn, and the weaving is effected elsewhere, chiefly by hand-looms; although there are many factories in which linen-cloth is manufactured by the aid of the power-loom.

The chief seats of the linen-cloth manufacture are, the north of Ireland, chiefly Belfast; the counties of Forfarshire, Fifeshire, and Perthshire, in Scotland; and the towns and neighbourhoods of Barnsley and Leeds, in Yorkshire. In Barnsley, the fabrics manufactured consist of linen, huckaback, diaper, duck, check, drabbet, tick, towelling, and union, a mixture of the staple with cotton. The fabrics made in Ireland are coarse and fine linens, canvas, sacking, and damask. The manufactures at Dundee are mostly confined to coarse linens, and sailcloth; while at Dunfermline, fine shirtings, damasks, and table-cloths, &c. are the principal fabrics made.

Bleaching and *calendering* are the processes which follow the weaving. The principles of bleaching have been already explained under APPLIED CHEMISTRY.

Prior to the introduction of machinery, the linen trade was very limited in extent. On the introduction, however, of improved mechanism, it increased rapidly. According to the Return of the Board of Trade, the declared value of the exports of the linen manufacture in 1852 was £4,231,786, and in 1853, £4,761,252. Linen-yarn was exported in 1852 to the extent of 23,928,592 pounds, value £1,140,565; in 1853, the number of pounds was 22,782,661, the value, £1,149,103. In 1881, the number of pounds was 18,250,200, and the value, £1,057,799; whilst the value of other manufactures of linen amounted to the large sum of £5,846,361.

Hemp and other Ligneous Fibre.

Hemp is the fibrous bark of the *Cannabis sativa*—a plant supposed to be a native of Persia or India, but which has long been naturalised and extensively cultivated in Europe, particularly in Italy, Russia, and Poland, where it forms an article of primary commercial importance. It is also cultivated to a considerable extent in many parts of America; but in Britain it is but little grown, except in a few districts of Suffolk and Lancashire. Its fibres are prepared for spinning in the same way as flax, and are made into yarn for the fabrication of canvas-bagging, sailcloth, ropes, and cordage.

Indian Hemp, which is imported from the East Indies, is the product of quite a different plant, *Crotolaria juncea*, a leguminous shrub resembling the Spanish broom of our shrubberies, which itself yielded fibre used in making the sailcloth and cordage of the ancient Roman navies. The Indian hemp is frequently known in trade by its native name, *Sunn-hemp*, or *Sunn*. The fibre is obtained from the bark of the young twigs.

New Zealand Flax is a very strong fibre, obtained from the long sword-shaped leaves of a *liliaceous* plant, *Phormium tenax*. Considerable quantities are used, but chiefly for cordage.

What is called Manila Hemp in commerce is the very long fibres obtained from the stems of the plantains and bananas, but chiefly from the one species, *Musa textilis*. It is best known by

the fine qualities obtained from Manila, but it is produced in almost every country in which the plants of the natural order *Musaceæ* are grown.

Coir is the coarse woody fibre from the husk or pericarp of the cocoa-nut (*Cocos nucifera*). It is the only product of the palm tribe (*Palmaceæ*) which is used in Britain for textile purposes, although no order yields a greater abundance of useful fibres. Coir is chiefly used in the manufacture of matting, for which it is now very extensively employed.

The beautiful Chinese linen called *grass-cloth* is now known to be made from the fibres of a plant closely allied to the common nettle—namely, *Bœhmeria nivea*, and one or two other species of the same genus, all of which grow in India as well as in China. In the former country, it is generally called *Rheea* fibre; and in the latter, *Tchou ma*, or China-grass. When properly dressed, it is perhaps the most beautiful of all known vegetable fibres; but neither in India nor in Europe has the art of dressing it after the Chinese method yet been learned. Much attention is now being paid to it, and rewards are offered by the Indian government for any invention which will enable the fibre to be properly and economically prepared.

The most important of all the ligneous fibres used for weaving purposes in Europe, after flax, is jute, the produce of *Corchorus capsularis*, a plant of the same natural order as the lime or linden tree (*Tiliaceæ*), which yields the bast of which the Archangel mats are made. At the beginning of the present century, jute was quite unknown in Europe; indeed, it is little more than thirty years since it began to be regularly used in our manufactories. Since then, its development has been enormous, chiefly in Dundee, where from 50,000 to 60,000 tons are annually consumed. It is chiefly used in the manufacture of sacking, and the bagging called gunny-cloth; but it is also employed in carpet-making and for ornamental matting, &c. The fibre of jute is very long—from five to eight feet; and the difficulties of dressing and spinning it into a yarn were at first very formidable, and prevented its earlier introduction. Now, the shipments of this fibre to Great Britain amount to over 200,000 tons annually.

COTTON.

The plants which yield cotton belong to the natural order *Malvaceæ*, and the genus *Gossypium*, of which about four species are supposed to yield the cotton of commerce. *G. herbaceum* of Linnæus yields the cotton of India, China, Egypt, and Italy; *G. arboreum* yields a small quantity only of East Indian cotton, and it is uncertain if it is exported; *G. Barbadense* yields the West Indian cotton, and the celebrated Sea Island and other varieties from the United States; and *G. Peruvianum* yields the cotton from Brazil, Pernambuco, Maranham, and other parts of South America.

Cotton-wool is merely an appendage to the seeds of the plant, which produces it apparently for the purpose of protecting the seeds from the effects of damp, which is very injurious to them; for the fibre is produced in the greatest abundance and of the longest staple in countries where, with the necessary high temperature, there is also a large amount of moisture in the atmosphere—a fact which is very generally lost sight of by those who seek to improve the quality of cultivation by careful culture in countries where the more important condition of atmospheric humidity is wanting. Few plants which are cultivated for useful purposes are more beautiful than the cotton. In a congenial climate and good soil, it grows about four feet high, and has a much branched bushy appearance. Its beautiful hollyhock-like flowers are produced in great profusion, and of various shades of rose-colour or yellow. The flowers consist of five petals in a cup-shaped calyx, surrounded by three broad bracts. They are succeeded by a pretty large capsule or pod, technically, in America, called the *boll*. It has from three to five compartments, in each of which lie the seeds, closely packed in their woolly covering, which is so hard pressed around them as to have a solid appearance just before perfect ripeness. When ripe, the capsule opens in several segments, and the woolly covering of the seeds loosens and expands around them, so as to lift them out and expose them to be blown away by the wind. They are gathered by the hand before this takes place, and being removed from the bolls, await the process of removing the wool from the seeds, to which it is firmly attached. There are two methods employed for the separation of the seed from its woolly covering. The more simple one is called *bowing*, and is performed by beating it with a string tightly stretched to a wooden bow; this method is very effective, and does not injure the fibre, but it is slow. The other is called *ginning*, the seeds being made to pass through an apparatus called a *gin*, which has a number of spikes or teeth so arranged as to pull the wool off without crushing the seed. This is an expeditious method; but an ill-constructed gin is very liable to break the delicate fibres. Saw-gins, consisting of a series of circular-saws, are in much favour at present; but the construction of the cotton-gin varies much, and it is by no means settled which is the best for the purpose.

If examined by the unassisted eye, the fine soft hairs from the cotton-seed appear perfectly smooth, and usually of a snowy whiteness; but no fibre is of any value for the purposes of the spinner which has a perfectly smooth surface; and the microscope reveals to us that each fibre is really a flat ribbon, which is bordered on each side with a raised and rounded edge, the section of which is like two *o*'s connected by a straight line, thus *o—o*; but the rounded edges often run off from one side to the other of the fibre, and thus give its flattened surface an appearance of being diagonally ribbed. Its chief economic value depends upon this construction, and renders it of all known fibres the most perfectly adapted for the spinner's purposes. It admits of being drawn out and twisted into a thread or yarn finer than any other; a pound of cotton has been spun of such extreme tenuity as to exceed a thousand miles in length.

The qualities of cotton used for manufacturing purposes are various; the most valuable is that known as 'Sea Island,' which is cultivated on the low marshy islands and plains on the coast of Georgia and South Carolina, in the United States of America. The staple of this quality is long and silky. The short-stapled quality, known as Bowed or Upland Georgia, is produced in immense

quantities in America. Cotton of good quality is imported from Egypt, where its cultivation was begun by Mehemet Ali in 1823. The supply obtainable from the East Indies is fast increasing in amount. When railways and canals open up the interior of our possessions there, and when as much care is taken in its cultivation and cleaning as is done in America, we may reasonably expect that our manufactories will be supplied to a large extent, if not exclusively, from these our own possessions. The West Indies also supply us with cotton. Brazilian cotton was first imported in 1781. Pernambuco cotton is very valuable, generally fetching a price next to that of Sea Island.

The value of cotton for manufacturing purposes is reckoned by the length, strength, and fineness of the staple, or fibres. The 'long-stapled,' or valuable cottons are Sea Island, Brazilian, West Indian, Egyptian; the 'short-stapled,' or inferior qualities are the Upland cotton of America, the Orleans, Mobile, and Surat.

The first authentic proof we have of the existence of the cotton manufacture in England, is a notice in a work published in 1641, in which the existence and importance of the trade, as carried on at Manchester at that period, are specifically mentioned. The progress of the trade was remarkably quick; in 1727, the population of Manchester, then, as now, the seat of the manufacture, had doubled.

In 1697, the quantity of cotton imported was about 2,000,000 of pounds; it took fifty years to increase this to 3,000,000; the next fifty years shewed a more satisfactory rate of progress, the importation at the end of that period amounting to 56,000,000. In 1850, the quantity imported amounted to nearly 525,000,000. In 1785, the first bag was brought from America. The quantity obtained from that country in 1850 was nearly 2,000,000 bales. A bale weighs, on an average, 300 pounds, the price per pound varying from 7¼d. to 5½d. In 1876, the importation amounted to 13,284,454 cwts., of the value of £40,180,880; the year 1881 shewed an increase, being 14,991,682 cwts., of the value of £43,834,647. In 1679, the total value of cotton goods exported from Britain was nearly £6000; in 1850, it reached a grand total of upwards of £28,000,000; and for the year 1881, it was over £65,000,000.

The introduction by Arkwright of the method of spinning by rollers was the turning-point in the history of the trade. Previous to this, the demand for yarn for weaving was always greater than the supply. But with the unlimited supply of the new process came also the increase of weaving. In 1850, the number of spindles at work throughout the kingdom was 21,000,000. In 1803, the first practical power-loom was introduced by William Horrocks of Stockport. In 1817, about 2500 only were in use; in 1835, this had increased to 116,801; and in 1850, to 225,000. In 1760, the manufacturing population was estimated at 40,000; in 1835, it had increased to 260,198; and in 1850, reached 332,124. In 1833, the number of mills in the kingdom was 1154, taking up a power of 41,000 horses in steam-engines and water-wheels. In 1839, the number of mills had increased to 2019; the horse-power to 59,856.

Arriving in England in a state far from clean, being mixed with a variety of extraneous matters, and the fibres much matted together, the cotton has to be further subjected to a cleaning process. This is effected by the *willow* or *willey*. A large conical drum rotates rapidly on a horizontal shaft, and is provided with a number of projecting spikes; the drum is covered with a case, in the inside of which are a number of spikes, so arranged as to pass between those in the drum as it revolves. The cotton is fed by an endless *apron*, at the smaller end of the cone, and is dragged between the spikes up to the larger end, where it passes into a case, from whence it is withdrawn by hand. The rapid rotation of the cone creates a sufficient draught to carry off the dust through a pipe. A machine called Hardacre's cotton-opener is much used instead of the willow. Two vertical shafts, *aa*, *bb*, fig. 9, rotate rapidly within a case, the sides of which have openings, leading the dust, &c. to a series of cells. The vertical shafts are provided with horizontal arms, which rapidly strike and open up the cotton, which is fed from the top, at *d*.

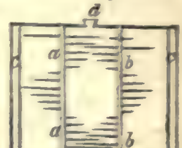


Fig. 9.

The cleaned cotton is now taken to the 'blower,' or 'scutcher,' fig. 10, where it is further cleaned,

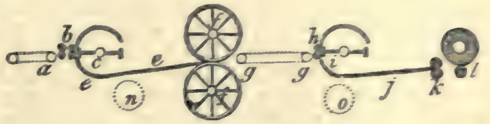


Fig. 10.

and the fibres separated one from another. The cotton being fed by the apron, *a*—made of a series of thin narrow wooden bars, fixed at their ends to two strips of leather revolving round rollers at each end—it passes between two pair of feed-rollers, *b*, revolving nearly in contact. On issuing from between the last of these, it is struck violently by the arms of a rapidly revolving beater, *c*, making some 1800 or 2000 revolutions per minute. The impurities pass from the cotton, and fall upon an inclined grating, *ee*, the cotton being wafted along to a second apron, *gg*, with a second set of feed-rollers, *h*, and again struck by revolving beaters, *i*, and finally passed to the floor. It is next taken to a second blower, similar in all respects to the former, excepting that instead of being delivered to the floor, it is passed through feed-rollers, *k*, and finally wound upon large rollers in the form of a continuous lap, *l*; hence the name of the machine, the lap-machine. In many cases, however, the blower and lap-machines are combined in one. The grating already mentioned is composed of thin bars of iron, set angularly, so as to present a series of edges to the cotton as it is whirled about by the beaters, thus further opening it. Between the first and second beaters, *c*, *l*, are two revolving hollow cages, *f*, *f*, with perforated periphery; the cotton is wrapped round this before being delivered to the second feed-rollers. A strong draught is created in the machine by fans, *n*, *o*, which aid in carrying off all the dust, &c. to the external atmosphere.

The action of all machines noticed has been to open the fibres of the cotton, and clear them of

adhering matter. This, however, has brought about a condition of matters not desiderated in the after processes—namely, a complete confusion of the fibres, causing them to lie in all directions one to another. It is the duty of the following machines to bring all the fibres parallel to one another. The more complete the parallelisation, the higher the quality of the yarn obtained.

If the reader will take a quantity of loose fibres of cotton, confused and twisted together, and place them between two brushes, and move the brushes parallel to one another, but in opposite directions, repeating the process several times, he will find the fibres lie parallel to one another. This is exactly the carding process. The teeth of the brushes or cards are, however, fixed upon revolving surfaces, and are not straight, but bent, as *a*, fig. 11. The revolving teeth act against the teeth of other cards fixed on a curved surface, and the inclination of which is in an opposite direction. There are two arrangements of carding-engines in use. In the first, a large cylinder, *bb*, fig. 11, rotates rapidly, provided on its surface with a series of strips of leather, in which the wire card-teeth are fixed. These rotate in close contact with a series of cards called flats, *c*, *c*, fixed in the inner side of the outer casing, which is of the same curve as the large cylinder. In the second arrangement, the large cylinder is retained; but it works in contact with a series of small cylinders, provided with card-teeth, which rotate less rapidly than the large cylinder: these are termed squirrels or urchins, or strippers and clearers. The flat and urchin systems are sometimes combined in one. The operation of the carding-machine on the combined system is as follows: The lap-roller, *b*, fig. 12, with its length of cotton-lap wound round it, is placed at the end of the machine, in bearings—the lap is withdrawn from this by two feed-rollers, *c*; it is then taken up by a small cylinder, *d*, furnished with card-teeth, and called the 'licker-in;' from this it is taken up by the large carding-cylinder, *a*, and delivered to the small strippers, *f*, *f*, which, rotating with less speed, hold the fibres to allow the large cards to act upon them; the flats, as *c*, *c*, fig. 11, also take the fibres up, the process being a continual delivering and redelivering from the large cylinder to the small ones and the flats. The cotton is ultimately taken from the large cylinder by another, termed the doffing-cylinder, *g*, on which the cards are fixed in spiral lines. To take the cotton from this is the work of the doffing-knife, which is a long flat blade, with one edge serrated, fixed at the ends to two connecting-rods, *h*, which have a quick up-and-down motion given to them by cranks at their lower extremities. The action of the knife is to strip off the cotton from the doffing-cylinder in a sheet of extreme lightness. This is gathered up, passed through a trumpet-mouth, *o*, and finally between revolving rollers, *m*, so as to form the cotton into a long, flat, and narrow ribbon, which, by means of ingenious mechanism, is coiled into long, narrow cans, in such a way as to occupy the least possible space. Two kinds of carding-engines are used in the manufacture—the breaker and the finisher. In the former, the cotton, after being carded, is delivered to rollers, and finally wound in a continuous sheet on a lap-roller. This 'lap' is carried to the 'finisher' carding-engine, through which it is passed, and finally coiled in the can, as above described.

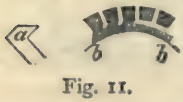


Fig. 11.

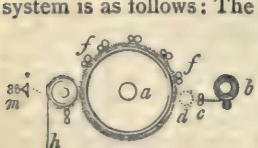


Fig. 12.

The next process is that of 'drawing,' the object of which is still further to parallelise the fibres. Let a tuft of cotton fibres be taken, and separated by means of the fingers; by repeating this process for some time, it will be found that the confused fibres will lie parallel to one another. Suppose three pair of rollers to revolve near one another, and a thin ribbon to be passed between them—if they all revolve at the same speed, the ribbon will go through unaltered; should, however, the last or third pair revolve faster than the first and middle pair, the ribbon will be pulled out or elongated somewhere between the first and third. This is the arrangement of the drawing-frame. In practice, the rollers revolve all at different speeds—the third faster than the second. This is the arrangement of the rollers in the finisher carding-engine. The drawing-frame, in which the process is more specially carried out, consists of a series of rollers, *aa*, *bb*, *cc*, fig. 13, the upper of which are covered with leather, and the lower fluted. A flat board, *d*, faced with flannel, presses on the upper rollers, by which they are cleared of all loose fibres. A number of slivers from cans, generally eight, are united into one, and passing over a grooved brass plate, are taken up by the rollers, and finally delivered to a can from between the rollers, *e*. The process not only parallelises the fibres, but tends to equalise the quality of the cotton, making the slivers of uniform strength and texture, by combining many slivers into one. This, which is called 'doubling,' is repeated until all defects are got rid of, and a uniform sliver obtained. Thus, in the first instance, eight slivers are passed through one set of rollers, increasing the chance of uniformity eight times—if four of these are again made into one, the chances are increased thirty-two times, and so on, till the last sliver may contain parts of 300 slivers. The process, however, for fine spinning is carried to a much higher rate of multiplication than this, sometimes exceeding 60,000 times. The distance between the rollers is regulated by the length of the staple. As all the cans sent from the drawing-frame must have the same length of sliver in each, should any of the slivers break, it is of importance that the machine should be stopped at once. This is effected by the machine itself, by the 'patent-stop motion.' The sliver passes to the rollers over a nicely balanced lever, which is kept in position by the friction of the passing sliver; when it breaks, the lever falls out of position, releases a lever which acts upon another lever, and passes the driving-belt from the fast to the loose pulley, and stops the machine. The drawing-frame is of considerable length, containing several sets of drawing-rollers.

Fig. 13.

The machine next used is called the roving, or slubbing, or bobbin and fly frame; the duty of which is to give the loose, porous, thick cord from

the drawing-frame a certain amount of twist, to enable it to be wound upon large bobbins. A series of spindles, *b*, *b*, fig. 14, are made to rotate with great rapidity vertically; these pass through a board, *d*, upon which rests a series of bobbins, *a*, up the central tube of which the spindles pass. The bobbins are made to rotate independently of the spindles, and at a different speed. To the top of the spindle, a fork is attached, the ends of which are bent downwards, so as to be on each side of the spindle like the letter U reversed, as *eg*. One arm, *g*, of this fork is hollow, and has at its lower extremity a delivering or spring finger. The sliver is passed from the drawing-rollers, *f*, attached to the frame down the hollow tube, *g*, of the fork, *eg*, and passed round the bobbin, *a*; the machine is now ready for operation, which may be described as follows: The degree of twist and winding in is entirely due to the difference of speed between the spindle and its attached fork, and the bobbin rotating on the spindle. The revolutions of the fork give the twist, the difference of speed between the bobbin and the spindle gives the quantity wound on the former. If the finger always remained at the same height, the cotton would be wound up at one place of the bobbin only; to distribute it equally over its surface, the frame on which the bobbins rest moves up and down. As the diameter of the bobbin increases, it is necessary, in order to lay the roving equally on, to decrease the speed—the decrease of speed being proportioned to the increase of diameter. This is effected by having a conical drum, the belt of which works the drum giving motion to the bobbins; as the belt passes from the small end of the conical drum to the large, its velocity decreases. The speed of the spindle and of the delivering-rollers being always equal, the quantity of roving delivered to the bobbins is always uniform; hence, as the bobbin surface increases in diameter, its velocity must be decreased, to enable the same quantity as before to be laid on during the same time. In place of winding the yarn round bobbins, as at *a*, *a*, it is sometimes wound round cylindrical spindles without ends, and made to assume the form shewn at A, fig. 14.

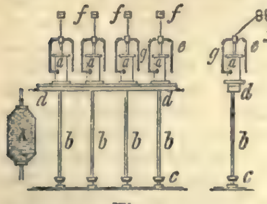


Fig. 14.

The bobbins, when full of roving laid uniformly on, are taken off the spindles by removing the fork, and put into skips, made of buffalo-hide, wicker-work, or gutta-percha, and conveyed to the next process.

The rovings thus produced are spun into hard, well-twisted yarn by two machines, the throstle and the mule; the former generally spins the harder kinds for the warp, and the latter the softer for the weft of woven goods. In the throstle, the arrangements are very similar to the roving-frame, with this exception, that the bobbins have no independent motion given to them by special means, the difference between the speed of the bobbins and the flyers or forks being caused by the friction of the bottom of the bobbins revolving in contact with a board faced with flannel; this board is called the copping-rail, and moves up and down, to distribute the yarn equally over the surface of the bobbins. The yarn drags the bobbin after it, but the weight of this and its friction on the rail keep it back, thus giving the twist by the difference of the speed.

In the mule, the yarn is not wound upon bobbins, but round steel spindles, and is built in such a way as to be thickest near the middle, gradually decreasing in diameter towards top and bottom; the bottom part, however, being much shorter than the upper, as shewn at *klm*, fig. 15.

Fig. 15.

The mule consists of two essential parts, one of which is fixed, and contains a row of bobbins from the fly-frame, ranged on a series of spindles, allowing them to rotate as the yarn is drawn from them. On the fixed head, the sets of drawing-rollers, *a*, are fixed. The other part of the mule is the carriage, *d*, which moves to and from the fixed head on parallel rails. The carriage carries a range of spindles, *c*, sometimes 1000 to 1200 in number. On these the yarn is laid to form cops, as they are termed. The spindles are made to revolve rapidly by bands passing from drums, *e*, round pulleys or 'wharves,' fixed at the lower extremities of the spindles.

To the carriage, standards are fixed, carrying a horizontal shaft parallel to the line of the spindles. This shaft is provided at intervals with curved arms, *g*, *h*, fig. 15; these supporting a slender wire, as *s*, *s*. The shaft to which the arms are attached is movable, so that the arms can be brought from the position at *g*, into that shewn at *h*. The operation of the machine is as follows: The carriage is brought up to the 'head;' the drawing-rollers, *a*, give out the yarn, which is wound round the points of the spindles, *c*, the faller-wire, *gs*, being in the position shewn at *sgf*; the carriage then moves outwards at a rate quicker than the yarn is delivered by the rollers, so as to stretch and equalise it; the drawing-rollers, when the carriage has gone out to some fifty or sixty inches, or a 'stretch,' as it is termed, cease revolving, so as to hold the yarn firmly. The motion of the carriage is greatly reduced in speed, while that of the spindles is accelerated; by this means the required twist is given to the yarn. On the carriage leaving the head, any yarns which may have broken are pieced or mended by little children, called piecers. The carriage is now disengaged from the mechanism which moved it on the rails, and the spinner begins his work. This consists of three operations, all of which must be done simultaneously, and with great nicety, to proportion all the movements to one another, on which the fineness and value of the yarn depend. These operations are—the pushing in of the carriage with his knee towards the head stock, or roller beam; placing the faller-wire in the position shewn at *hs*, fig. 15, so as to bring all the threads to the level of the bottom of the cop; and, lastly,

to turn a wheel, by which motion is given to the spindles, at a speed proportionate to the movement of the carriage. Previous to performing these operations, he causes the spindles to revolve in the wrong direction, so as to throw the yarn off the points of the spindles, which was delivered to them during the stretch last completed. On approaching the head, the attendant brings the faller-wire gradually up to the position shewn at *gsf*, fig. 15, thus preparing for another stretch. The carriage mechanism is then put in gear with the main driving-shaft, and the operations above described are again gone through. Thus, by a succession of operations, the yarn is finally built up into cops, which, when finished, are stripped from the spindles and put into baskets. In the self-acting mule, all the operations are done by machinery, and the only attendance required is that of piecers and menders, the latter being adults. The following illustration shews a range of mules at work.

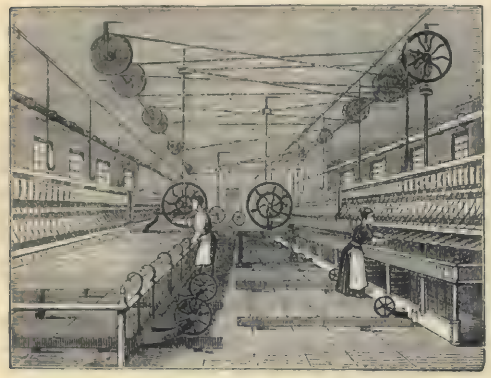


Fig. 16.

To be ready for weaving purposes, the yarn from the bobbins or the cops is placed upon larger bobbins by the winding-machine, in which the small bobbins from the throstle, or cops from the mule, are placed either vertically or horizontally. The threads from these pass through glass 'eyes' or hooks, fixed to a guide-bar, which has a lateral to-and-fro movement given to it; and are thus evenly wound upon the surface of the large bobbins. These are taken and placed horizontally on axes placed in the frame, *d*, of the warping-mill, fig. 17. The threads or yarn from a number of these are passed through glass eyes, in a heck-box, *e*; which is suspended by a cord passing over a pulley, the termination of which is wound round the main axis of the upright skeleton framework, *aa*. As the latter revolves, the cord is wound round the axis, and gradually raises the heck-box upwards. On the framework revolving in the contrary direction, the cord is unwound, and the heck-box descends. By this arrangement, the yarns are wound spirally round the frame, the circumference of which is so designed that it serves as a measure of the quantity wound upon it. Motion is given to *aa* by the crank *c* and pulley *b*. The heck divides the yarn into two sets, one for each heald of the loom.

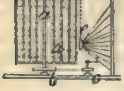


Fig. 17.

The sets, or the 'lease,' of yarn are taken off the frame and wound up in a ball, and taken to the beaming process. The yarn in this is laid on cylinders or beams, and each thread distributed equally, by passing through between shreds of cane fixed in frames. The warp thus formed, is next dressed in the dressing-machine, by which each thread or yarn has a portion of flour-size well rubbed in by brushes and rollers into its fibres. When dried, the warp is stiff, and easily drawn through the healds of the loom, for which it is now prepared. The supply of yarn in the shuttle is always derived from a cop, so that yarn for a weft is never made in the throstle, but always in the mule. We shall, under the head of Wool, describe the movements of the ordinary loom, so that it is unnecessary here to advert to the movements of the *power-loom*, which are exactly similar, but produced by steam-power instead of manual labour. In the annexed engraving (fig. 18) is presented a view of the interior of a power-loom apartment. All the looms are of iron,

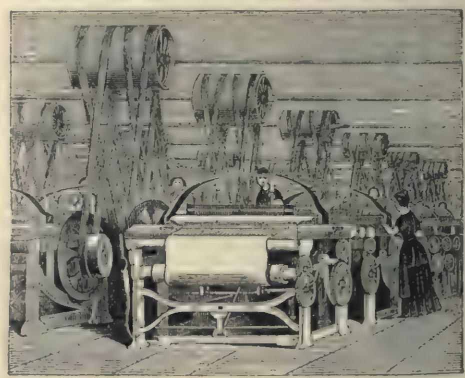


Fig. 18.

and moved by belts from shafts, the shafts being turned by steam or water power.

SILK.

This beautiful material, which differs essentially from all others used for textile purposes, is produced by several insects in their *larval* state, and is used by them to form a protective covering during their inactive condition as *pupæ*. The larvæ, or caterpillars, of the silk-producing moths are very voracious feeders, and are provided with two very large glands, called *sericteria*, which secrete the silk in a fluid state from the food in its passage through the digestive organs. When these glands are fully charged with their secretion, the animal stops feeding, and seeking a suitable situation, in a state of nature amongst the small twigs of a tree, it begins to emit, through very minute openings called spinnerets, situated in the back of its throat, and in close connection with the glands which secrete the saliva, the fluid silk, which becomes a hard thread at the moment of its emission, and is projected through the saliva, which is of a gummy character, and readily adheres to any point to which it is applied. The insect then curves its head round and round, continuing to draw out the thread of silk, and forming a close and compact covering around itself, for wherever one part of the thread touches

another, it adheres, until the contents of the *sericteria* are exhausted; and the animal is, in its now shrunken condition, entombed in a silken and nearly close-fitting case of a white or golden colour, called a cocoon. But the material is not uniform throughout: at first, that which formed the outside of the cocoon was coarser, less lustrous, and in a less distinct thread than that which formed the next layer, in which the thread is clear and distinct, and has a beautiful glossiness; after this, again, the innermost layer is confused, and so closely gummed by the saliva that it has the appearance of a kind of paper. In consequence of these characteristics, only the middle layer can be unwound as a thread and used for weaving; and formerly, the outer and inner layers were regarded as waste, and were thrown aside as useless; they are now, however, utilised. Before proceeding to describe the processes required to fit either kind of silk for the purposes of the weaver, it will be well to mention the names of the insects which yield silk of commercial value; there are many, besides, which have not been found of further use than that which nature designed for them. The first in importance, and the one which is, *par excellence*, called the *silkworm*, is the *Bombyx mori*, or Mulberry Bombyx, from its feeding upon the leaves of the white mulberry-tree when in a state of nature. It will, however, in captivity feed upon some other plants, such as the lettuce, mallow, and some other plants which have milky juices, from which it is supposed to secrete the silk. The following species of Bombyx are also feeders upon the white mulberry-tree—namely, *B. crossa*, *B. textor*, *B. sinensis*, *B. Huttoni*, *B. Horsfieldi*, all natives of India or China; and they yield silk which has been used, and the animals have some of them been beneficially crossed with the common silkworm. Besides these species of the genus Bombyx, there are species of other genera which yield useful silk, and foremost amongst them is *Antheræa Paphia* of Linnæus, the Tusseh moth, yielding the greater part of the silk called 'Tusseh' or 'Tussur' silk, a coarse kind much used in India in weaving a coarse fabric known in commerce as Tusseh silk, which is now in frequent use in this country for coat-linings and other purposes. The following species of Antheræa are also said to yield a part of the Tusseh silk used: *A. Frithii*, *A. Larissa*, *A. Helferi*, *A. Pernyi*, *A. Mezankooria*, *A. Jana*, *A. Roylei*, and *A. Perottetti;* whilst another species, *A. Assama*, produces a silk used in India under the name of Moonga, or Moogha, of which a finer cloth is made than that from the Tusseh-silk.

The genus Attacus is next in importance to that of Antheræa. *Attacus Cynthia* yields the Eria silk, which is woven into useful and beautiful fabrics in India, China, and Java. In India, it is known as Eria or Arindy silk. Of much less importance is *A. Edwardsii*, *A. Guerini*, *A. atlas*, and *A. Ricini*. The last, from its choosing the castor-oil plant as its natural food, was thought a very promising subject for rearing in Southern Europe; its culture has, however, not advanced. A cross-breed between *A. atlas* and *A. Guerini* has been introduced into Europe, and great hopes were felt that it would prove of great value, as it is able to bear our climate even as far north as Perthshire, and it feeds upon the leaves of the Ailanthus, an equally hardy tree; but, like others, it has not yet become practically useful. The following are more or less used in India, China, and Java as silk-producers: India—*Actias Selene*, *Caligula Simla*, *C. Thibeta*, *Neoris Huttoni*, and *Saturnia Grotei;* China—*Saturnia pyretorum;* Java—*Cricula triferrestrata* and *Læpa Katinka*.

It will surprise many that the silk used by man is produced by so many insects, and we have been thus particular in naming them, because it is too common an error of books to lead to the conclusion that one only, the *Bombyx mori*, is the sole producer. It is true that it yields a very large proportion of all that is woven in Europe, and even in India and China; but since the discovery of the method of using waste silk, we receive such mixtures from abroad, that it is impossible to say that we do not use the silk of any or all of the above-mentioned species.

It is mentioned above, that the cocoon of the common silkworm consists of three layers, all differing in the quality of the silk. For textile purposes, we can only separate them into two—namely, the middle one, called *raw silk*, capable of being unwound or *reeled* off; and the outer and inner layers, which are called *waste silk*. The greater number of the other species only yield the latter kind, and as the art of using it is only of recent discovery, they are comparatively little known.

The first process in the preparation of silk for the weaver is to carefully sort the cocoons into their different qualities and colours; then they are soaked in warm water, to soften the gummy matter which cements the threads together, and the worker carefully removes the outer layer with a small instrument, usually a pointed bit of wood. The *waste* is thrown aside for other operations, and the layer of windable silk being exposed, is ready for reeling. The great point in reeling is to make the thread of as even a thickness as possible: *perfect equality* is scarcely attainable. An experienced reeler, with the assistance of a girl to turn the wheel, can with ease wind off a pound of silk in a day.

A number of cocoons are placed in a dish of warm water, in order to dissolve the gummy fluid already mentioned, and allow the thread to be taken off. The reeler uses a whisk of fine twigs to take up the loose points, which she passes in sets of about five through the eyes of the machine. These compound filaments, after being made to cross and rub on each other so as to clean their surfaces, are combined first two and two, and finally all together into a single thread, which is wound upon a reel or frame, and formed into hanks and skeins.

Raw silk, preparatory to weaving, must be made to take one of three forms—respectively termed *singles*, *tram*, or *organzine*. *Singles* is merely the raw silk twisted, in order to give more firmness to its texture. All raw silk, for whatever manufacture designed, must undergo this process. *Tram* is formed by twisting together, not very closely, two or more threads of raw silk, and this generally forms the weft, or transverse threads of the web. *Organzine*, which is principally used for warp, is produced by a very elaborate process, of which it would be impossible to convey any correct idea to the general reader without the aid of a diagram. The principle of the process, however,

may be generally stated to be like that of making rope, where the combined strands are twisted in an opposite direction to that given to the separate threads, and this is accomplished by giving a reverse motion to the machinery; whereas singles and trams are twisted only in one direction, similarly to twine, or to the individual strands of which the larger rope is made. Silk thread intended for organzine is in the first process twisted in a left-hand direction.

The preparation of raw silk, that is, silk in the hanks as imported, is carried on as an especial trade—that of the silk-throwster in large factories, with expensive and complicated machinery suited to the different processes.

The first to be noticed is that of *winding*. In this operation, the hanks are stretched on a light hexagonal reel, termed a swift. The silk is led from these to a series of bobbins placed horizontally in a frame, some distance above, and in advance of the reels, one bobbin being allotted to each reel. The threads of silk are wound upon the bobbins, uniformly over the surfaces, by being passed through eyes which are placed on a bar having a lateral movement to and fro. The silk thread thus wound upon a series of bobbins is next cleaned—that is, each thread is made to pass through an aperture; but before passing through the hole, the silk is cleaned from dust by coming in contact with a brush.

The next operation is that of *throwing* or twisting. The silk bobbins from the previous machine are placed horizontally in a frame in one or two rows, one above the other; at a little distance below these horizontal bobbins are placed a series of vertical ones; these, however, have no motion on their axes, like the horizontal ones, but are stationary. A spindle passes through a central aperture on each of the bobbins, and is made to revolve quickly. At the upper end of the spindle, a small flyer (see Cotton) is fixed. The silk is passed from the horizontal bobbin through the eye of the flyer, and by the rapid rotation of the latter round the vertical bobbin, it is wound upon its surface, receiving at the same time a twist. The amount of twist given to the thread is dependent upon the difference of speed between the flyer and the horizontal bobbin which gives out the silk.

In the manufacture of tram, sewing-silk, and organzine, the next process after spinning is that of *doubling*. The bobbins, equal in number to the threads to be united, are set in a frame, the loose ends of the silk of the bobbins are collected, and passed through a loop, and finally wound round a horizontal reel. This is placed in the throwing-machine, and the ends carried through the eye of a flyer, which, by its rapid rotation round a bobbin, winds it upon its surface, giving it at the same time the desired twist. A number of bobbins and flyers are arranged in one machine, and an apparatus attached, by which, when a thread breaks, the flyer with which it is connected is stopped.

Waste silk, which was, until some time early in the present century, thought to be valueless, has now become an important material, for it is now *willowed*, or torn out of its entangled state, and combed and spun like flax, then spun into yarn, and woven into the various fabrics known under the general name of spun-silk.

The statistics of silk are very interesting. A cocoon of the largest size will not yield more than 5 grains of *raw silk*, and about 23 of waste. It takes, therefore, at a fair calculation, 1400 silkworms to produce one pound of *raw silk*. The imports of raw silk into Great Britain in 1866–1870 were 6,307,575 lbs. or the produce of 8,830,605,000 silkworms. Besides *waste silk* to the extent of 3,512,320 lbs. there were also imported 283,723 lbs. of silk prepared as *singles*, *tram*, or *organzine*. The total value of these quantities was £9,297,249, in addition to which manufactured silk goods to the value of £15,244,816 were imported. The imports of raw silk for the three years 1879–81 amounted to 10,464,951 lbs., value £8,981,702; while the manufactured goods were valued at £37,155,203. These figures for the British trade should at least be multiplied by five, to give the consumption of the whole world.

WOOL.

Wool, according to the definition given by Professor Owen, 'is a peculiar modification of hair, characterised by fine transverse or oblique lines from 2000 to 4000 in the extent of an inch, indicative of a minutely imbricated scaly surface when viewed under the microscope, on which, and on its curved or twisted form, depends its remarkable felting property, and its consequent value in manufactures.' This will be seen in figs. 19 and 20, in

Fig. 19. Fig. 20.

which the wool is slightly magnified, to shew the curled character. In fig. 20, two varieties are shewn in section (*a*, *c*) and complete (*b*, *d*), giving the scaly characters. Wool, although principally derived from the sheep in its many varieties, is obtainable also from the goat and other animals. The Tibet goat furnishes the finest of all wool; the merino sheep the next best.

Wool, as used in our manufactures, is divided into two sorts—the long, or combing, and the short, or carding wool. These, again, give rise to the two grand divisions of the trade—the *woollen*, or the short-wool, and the *worsted*, or long-wool departments. It is our duty to explain briefly the various processes gone through in these, taking the *woollen* as first in order.

The wool of the sheep is removed from the animal whilst alive, or from the skins after death; in either case it is found that there are several different qualities, dependent chiefly on the length of staple in each fleece. The *wool-stapler* therefore takes it in hand, and, with great skill and rapidity, separates one from the other into three

classes—*primes*, *seconds*, and *thirds* being the gradations generally used. To free the wool from the animal grease, and enable it to take on the dye, it is *scoured*. The dyeing either takes place at this stage, or is deferred till the cloth is woven: when the latter is the case, it is termed *piece-dyed*, when the former, *wool-dyed*.

The wool is now subjected to the action of the *willow*—much resembling in arrangement and operation the machine of like name in the cotton manufacture. The wool is opened up and projected from the machine in a loose open condition. It is afterwards picked, to free it from all burrs and extraneous matter, and to separate the locks which differ in colour. A machine has been recently introduced, named the burring-machine, which effectually frees the wool from all burrs, &c. Previous to passing through this machine, the wool is well oiled, to render its working more easy. If the burring-machine is not used, the wool, after being picked by hand, is oiled, and passed through the willow a second time. After this is done, it is passed to the scribbling-machine, which is very similar to the breaker carding-engine used for cotton. In the carding-engine, the next machine in sequence, the card-teeth are placed in the main cylinder in the form of narrow strips. The wool is thus passed from the machine in the form of long narrow bands. Each band, as it issues from the machine, passes between a fluted roller and a semicircular case which embraces it; by which means it is rubbed round into the shape of hollow tubes, equal in length to the breadth of the band of wool from which they are cut. The tubes of wool, termed cardings, are next passed to the 'slubbing-billy,' the operation of which is similar to that of the cotton roving-machine. The rolls, or tubes of wool, are placed lengthways on a sloping board in front of the machine, and are taken up by the drawing-rollers. The tubes of wool being all of a determinate length, it is necessary to add new lengths to the ends of those passing through the rollers, in order to maintain the continuity of the sliver of wool. To maintain the supply is the duty of the little attendants called 'pieceners.' The wool is finally wound upon the bobbins or spindles, ready for the mule, where it is spun into yarn for weaving. The three preliminary processes are thus seen to be scribbling, carding, and slubbing. By means of a machine known as Mason's (of Rochdale) condenser, introduced some years ago, and now being rapidly extended in use, a vast deal of labour is saved in the way of 'piecening,' and the three operations of feeding, piecing, and slubbing are effected by one machine.

The yarn prepared by the mule is then woven into cloth, and ready to be put through the succeeding operations, as follows: The oily matter is removed from the cloth by scouring, in order to restore the roughness to the fibres, preparatory to the subsequent process of milling. In articles made of long wool, the texture is complete when the stuff issues from the loom. The pieces are subsequently dyed, and a gloss is communicated to them by passing them between heated metallic surfaces. But in cloths made of short wool, which is generally dyed before being spun, the weaving cannot be said to complete the texture. When the web is taken from the loom, it is too loose and open, and consequently requires to undergo another operation, called *fulling* or *milling*. This is performed by a fulling-mill, in which the cloth, being first freed from its oil by the use of fuller's-earth and other detergents, is immersed in water, and subjected to repeated compressions by the action of large beaters, formed of wood, which repeatedly change the position of the cloth, and cause the fibres to felt, and combine more closely together. By this process, the cloth is reduced in its dimensions, and the beauty and stability of the texture materially improved.

The process of milling is now rendered much more speedy and economical by the use of the milling-machine, which does the same amount of work at a less expense of detergent material. In this machine, the cloth is fastened together so as to form an endless rope, as it were, and subjected to the action of weighted rollers, which press it against the sides of the trough or case in which they work; soap is passed to the cloth through doors made in the machine for this purpose.

This tendency to become thickened by fulling, is peculiar to wool and hair, and does not exist in the fibres of cotton or flax. It depends on the fibres or hairs being barbed or serrated, so as to admit of motion in one direction, but not in another. There thus results an entanglement of the fibres, which serves to shorten and thicken the woven fabric.

The nap, or downy surface of broadcloths, is raised by a process which, while it improves the appearance, tends somewhat to diminish the strength of the texture. It is produced by carding the cloth with the barbed or hooked fruit-cone of the common teasel (*Dipsacus fullonum*), which is cultivated in England for the purpose. This operation extricates a portion of the wool, and lays it in a parallel direction on the right surface of the fabric. Teaseling was at one time performed by hand, a number of the heads being placed in a small frame; machinery is now employed, the teasels being arranged on a revolving cylinder, with which the cloth is made to pass in contact in a direction contrary to that of its revolution. The nap thus formed is then cut off to an even surface by the process of *shearing*. This is performed in various ways; but in one of the most common methods, a large spiral blade revolves rapidly in contact with another blade, while the cloth is stretched over a bed or support, just near enough for the projecting filaments to be cut off at a uniform length, while the main texture remains uninjured.

The cloth is finally prepared for market by a series of finishing processes, as hot-pressing, boiling, and steaming. In the former, the cloth is subjected to enormous pressure between hot plates. Boiling consists of immersing the cloth, tightly wound upon a roller, in warm water, after which it is dried in a hot room while tightly stretched out. In steaming, the cloth is wound upon perforated rollers, into which steam is admitted. After all this, it is closely examined, to take out all unevennesses, and to make up any minute holes in the fabric; and, finally, it is cold-pressed, and made up into bales, when it is ready for the market.

The second branch of the woollen trade is the worsted or long-wool manufacture. The principal operations in this department being analogous to

those of the cotton manufacture, a very brief glance at their nature and sequence is all that is necessary.

The wool is first washed and cleansed, much of the moisture being pressed out after this operation by passing it between rollers. The wool is next dried, and afterwards passed through a species of willow, which opens, cleanses, and straightens the fibres, which are now ready for combing. This is a very unhealthy and tedious process, being carried on in hot rooms. The process consists in placing wool fibres on a comb, evenly laid and firmly fixed between the teeth, and passing the teeth of a second comb through the mass. The teeth of the combs are heated in a stove, so as to render the wool soft and pliant. Each comb has three rows of teeth of different heights: a portion of the wool is left, called *noil*, which the comb will not straighten; this is used for coarse yarn. Machines have been introduced to supersede this process; one of these, invented by Mr M. C. Lister of Bradford, in Yorkshire, is a marvel of ingenuity, and is perfect in its operations, combing out the longest stapled wool, and removing the *noils* from it. Equal in ingenuity, but not in originality, is a still newer machine, which combs even short-staple wool, at least wool from 2½ to 4 inches in length; it is the invention of Mr Noble, and is called 'Noble's Combing Machine.' These two really wonderful machines have done more to sustain the prosperity of the worsted trade of Yorkshire than any other circumstance, and have led to a surprising economy of labour and material. The combed wool is spun into yarns by the ordinary spinning-machinery.

Woollen fabrics may be classified as follows:

1. *West of England Coatings.*—These consist of doeskins, stout hand-woven cloths, firm in texture, milled, and finely dressed on the face; cassimeres, resembling doeskins, but woven in a somewhat different way; beavers, also stout, hard milled cloths, only dressed on the face; Sataras, Venetians, Meltons, deerskins, diagonals, &c.

2. *West of England Trouserings*, of which there are similar varieties to those amongst the coatings, with the addition of kerseymeres, and a particular kind of ribbed cloths called Bedford cords; but this class of fabrics is usually of stouter quality, and only 27 inches in width, instead of from 54 to 62 inches, as in the coatings or broadcloths.

3. *Yorkshire Woollens*, consisting of coatings, trouserings, of lower qualities usually than those of the west of England, and often containing admixtures of cotton and other materials—railway rugs, and the now fashionable imitations of sealskin, Astracan, sheep and lamb skins, dogskins, &c.

4. *Scotch Tweeds*, which are loosely woven fabrics, have obtained great celebrity, and constitute a very extensive and important manufacture, chiefly in Scotland.

5. *Flannels*, of whatever variety, are all loosely woven; *baize* is a kind of flannel with a tufted nap; and *blankets*, of which there are many varieties manufactured in different parts of the country, are also loosely woven, and finished with a long nap raised by rollers covered with brass pins. Besides the manufacture of cloths, blankets, and flannels, the department of woollen fabrics comprehends *carpets* and *hosiery*, two very distinct but important branches. Three kinds of carpets are usually made—Venetian; Kidderminster, Axminster, or velvet-pile; and Brussels. Venetian carpeting is a plain fabric, composed of thick linen woof on a woollen warp, and is employed chiefly for stair or lobby coverings. The Kidderminster carpeting is by far the most common; it consists of two woollen webs, woven together, and intersecting each other at particular parts, so as to produce definite figures of different colours. The manufacture of this species of carpets has been long carried on with advantage in different parts of Scotland. Brussels carpets possess a basis of strong linen threads, on which the pattern in woollen is thrown up in loops, which are kept firm by small rods. When the web is woven, the rods are pulled out, leaving a soft surface of the closed ends of loops. Latterly, a great improvement has been made in carpet-weaving, which has also been adopted for shawls. Instead of using threads of one particular colour throughout, and throwing up the threads as they were required to form the pattern, the plan is to dye different parts of the same thread with different colours, suitable to the pattern required. Thus, a single thread may be dyed in patches of red, yellow, black, or any other colour, and it performs its part in the pattern through its entire length: the saving of material by this ingenious mode of dyeing is immense.

The classification of worsted stuffs is as follows: 1. Fabrics composed entirely of wool; 2. Of wool and cotton; 3. Wool and silk; 4. Wool, silk, and cotton; 5. Of alpaca and mohair, mixed with cotton or silk. 'The first of these divisions comprises the well-known fabrics called merinoes double twilled, so denominated from the Spanish wool of which they were first manufactured. (Bradford produces goods of this class little inferior to the French merinoes.) In single-twilled merinoes, the worsted manufactures of Yorkshire have at all times had the decided precedence. Shalloons, says, serges, lustrings—all stout and heavy articles—are manufactured chiefly at Halifax and Keighley. Damasks for curtains and hangings are also made at Halifax, and this branch of the trade has arrived at great perfection, both in excellence of material and elegance of design. Of the fabrics composed of wool and cotton, the articles denominated Coburg and Orleans cloth—the former being twilled, and the latter plain—have been staple manufactures, of which the consumption has been immense; they are made chiefly at Bradford and Keighley. Many of the silk-warp and worsted-weft fabrics are distinguished by their richness and durability. The alpaca and mohair manufactures—carried on at Saltair, Queensbury, and Bradford—are remarkable for their softness and brilliancy, and the great variety of purposes to which they are applicable. It is in the production of articles in which wool of various kinds is combined with cotton and silk, that the superiority of the British manufacturer is most apparent. The consumption of these various manufactures is immense; the looms are capable of producing upwards of 200,000 pieces per week, averaging thirty yards each.' In 1881, the British imports of wool amounted to 450,141,735 lbs., of the value of £26,011,024; and the value of the exports of manufactures from this material

was about £20,000,000, a vast sum in addition to the home consumption.

WEAVING.

In describing the process of *weaving*—an operation common to all textile manufactures, it will be sufficient to treat of it as performed by hand; for the principle of the power-loom is the same, the only difference being in the motive power. A certain number of threads arranged alongside of, and parallel to each other, constitute the *warp*. This is evenly wound on the beam, *a*, fig. 21, of a loom, and is thence extended to another beam, *b*, at the opposite end. Between the beams are suspended two 'healds,' or 'heddles,' seen edgewise at *f*, *g*, fig. 21. A front view of one is presented in fig. 22, where *g*, *h* are two bars, between which cords are stretched, each having a loop, *f*, in the middle. The threads of the warp are drawn through these loops, a thread passing through a loop in each heald alternately. The healds are united by a cord which passes over a pulley, *h*, fig. 21. The bottom bars of the healds, *f*, *g*, are connected to 'treddles,' *d*, *e*; by pressing an end of which alternately, the weaver sitting on *c* can raise and depress *f* and *g*. The threads of the warp, after passing through the loops of the healds, are taken through the openings or 'dents' of the reed, *b*, fig. 22, attached to the batten or lay, *aa*, which swings to and fro on the frame, as at *ii*, fig. 21. The rising and falling of the healds cause one set of the threads to be raised and the other depressed, so as to cross each other, and make an opening, or 'shed,' as it is termed, from one side of the warp to the other. Every time that the threads are opened, a shuttle, containing the *woof* or *weft*, is thrown across from one side of the warp to the other, and the thread of woof thus left is driven home by a lay, or properly by a comb-like process of reeds called a *dent*, which the lay brings forward. A reversal of the warp makes another opening, which is similarly crossed by the shuttle, and so on, each cast of the shuttle adding to the woven fabric by the breadth of a thread.

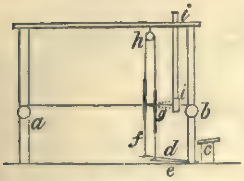


Fig. 21.

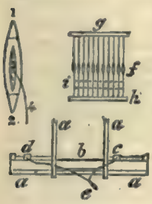


Fig. 22.

The shuttle is formed of hard wood, and shaped like a canoe; it is hollowed out in the middle, to afford space for the cop to lie in; the thread of which is brought through a hole in the side. Small wheels are sometimes provided to the shuttle, to enable it to run easily in the 'race.' The shuttle is driven through by what is called a 'fly' and 'picker.' Two pieces of wood, *c*, *d*, fig. 22, known by the latter name, move along a wire, and are connected by a cord, to which a handle, *e*, is attached; by jerking this from side to side, the pickers send through the shuttle with great force.

The only changes of pattern which can be readily produced by plain weaving are stripes or checks—the way of effecting which is obvious enough. *Twills* are formed by causing the thread of the weft to pass alternately over two or more, and one of the threads of the warp, and performing the reverse in its return. In ornamental or *figure* weaving, an expensive, or at least complex, harness is required, the warp being of various depths, several sets of heddles being also in requisition, and it may be a number of shuttles, each having its own system of thread or threads. Looms of this kind, whether for linen, silk, cotton, or carpet fabrics, are known as draw-looms, the most perfect of which is that invented by M. Jacquard, a practical weaver at Lyon. With modifications adapted to the object in view, the Jacquard-loom has now superseded all others for figure-weaving—the skill and labour required to work it being little more than that necessary for plain weaving.

FELT—HATS—STRAW-PLAIT.

Felting is the process by which different kinds of hair, fur, or wool are blended into a compact fabric, without undergoing either spinning or weaving. It depends upon the scaly structure of the fibre—a structure which has already been noticed under wool, and which may readily be observed by passing a fibre of wool through the fingers in opposite directions. This peculiar structure allows the fibres to glide amongst each other, but only in one direction; so that when the mass is agitated, the root end of each fibre is pushed forward among the rest lying in the same direction, but its scales become locked in those lying in the opposite position. Felting is now largely applied to the manufacture of cloths for wear, decorative purposes, coffin covering, &c. and is made of sheep's wool, often mixed with even vegetable fibres. Druggets are also made by this process.

Straw, *plaited*, or otherwise worked into a fabric, is in use in almost every country as a material for a light and ornamental head-dress. Many of the tropical grasses, and palm-leaves finely split, are eminently fitted for this species of manufacture, and thus navigators often bring from the Indian Archipelago and South-sea Islands hats, fans, baskets, and other articles, exhibiting a beauty of texture and intricacy of design which the most expert straw-plaiter in Europe could scarcely surpass. *Split-straw* is an elegant manufacture for women's bonnets. The straw of wheat or of rye is cut at the joints; it is sorted into small bundles, and is next split by means of a very simple instrument, and delivered to be plaited. It is sewed by the bonnet-makers, and then blocked, which is a laborious process; and after being pressed, wired, and lined, is ready for sale. Of straw-hats, the *Leghorn* are the most highly prized, as the finest in the world; they are made in the neighbourhood of Florence, Pisa, the district of Siena, and the upper part of the vale of the Arno, and are exported from Leghorn. About thirty-five years ago, a firm established straw-plaiting in the Orkney Isles, and adopted rye-straw as the material. At first, there seemed some prospect of success; but it does not appear that the competition of foreign-grown straw could be successfully met. Various other materials

besides straw are used for making light hats. *Chip*, which is thin strips of willow wood made by a plane, is employed.

PAPER.

The earliest kind of paper, or material for writing on, of which we have any account, was the *papyrus*, used by the ancient Egyptians; and hence our modern word *paper*. The papyrus was a plant, a kind of gigantic rush (*Papyrus antiquorum*), from which thin fibrous membranes were stripped, and the membranes being pressed together, formed small sheets of a rude kind. The Chinese are said to have understood the art of making paper in very early times; but whether Europeans learned it from them is not clearly known. The art was introduced amid the obscurities of the middle ages, and most likely through the ingenuity of the Arabians. In the beginning of the 14th century, a paper-mill was established at Nuremberg, in Germany; and in 1588, a mill was erected at Dartford, in England. Little progress was made, however, in the manufacture of paper in this country before 1770, when the first mill for fine paper was established at Maidstone by the celebrated J. Whatman. The previous supply had been derived principally from France and Holland.

The principle on which paper is made is very simple: a portion of linen rags, or other suitable vegetable material, is ground to pulp; this pulp is shaken in a fine wire-sieve, so as to settle in a thin cake, or sheet; the sheet is pressed, in order to squeeze out the liquid; and when dry, we have a sheet of paper. This is the ordinary hand-process, but paper is now made with few exceptions by very complicated and beautiful machinery, which, instead of sheets, forms webs of any desired length.

Preparation of the Rags.

After the rags arrive at the mill, they are picked and sorted into four or five qualities. All substances not suited for paper-making, or which might injure the machinery—such as pins, buttons, pieces of silk, and woollen cloth—must be carefully removed. The rags are then cut up into pieces about four inches square, by bringing them up against the standing edge of a fixed knife. After being cut, they are well agitated in a cylinder, which frees them from particles of dust. The rags are then boiled in an alkaline lye composed of caustic soda.

After being boiled, the rags are carried to the first washing-engine, which consists of a large oblong stone trough, into which a stream of water is allowed to flow, and to escape by the other end. This cleans the rags most effectually, the run of water carrying away any impurities that may still adhere to them. On one side of this trough is an engine, which again washes and grinds the rags, and is termed by the workmen the *breaking-in machine*. This powerful apparatus consists of an elliptical-shaped trough, made of lined iron; within it, a grooved roller revolves horizontally over the surface of a sharply grooved elevation (fig. 23, *ac*), by which the rags are torn to shreds. The grooves on the roller, and those on the plate, act upon the pieces of rags much in the same manner as cutting with a pair of scissors. The trough is half-filled with water, which comes in at one end, and escapes through holes at another part, the direction of the current

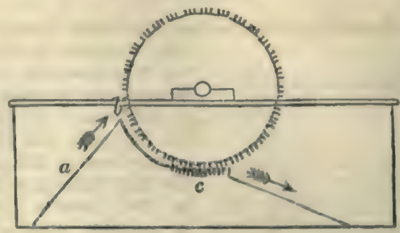


Fig. 23.

being shewn by the arrows in fig. 23. The operation of *grinding*, as it is called, occupies about an hour and a half; and when the rags are sufficiently reduced to a pulp, the stuff is passed down from the trough to the draining-boxes. On reaching the draining-boxes, the water is allowed to run off from the pulp previous to the bleaching process. The common method of bleaching is to steep the pulp in a solution of chloride of lime, by which the fibres are not so much injured as when chlorine is used. In bleaching, great care should be taken that the solution is not too powerful, or the texture of the paper may be materially injured by the process.

After bleaching, the pulp is again put into a washing-machine, to free it thoroughly from the bleaching-liquor. This process is similar to that previously described, except that the roller is screwed down closer to the fluted plate, so as to reduce the pulp to a finer consistence.

From the second washing or beating machine, the pulp is passed down to a large tun or vat, called the *stuff-chest*, which is merely a reservoir to keep the pulp till it is put into the machine which converts it into paper. This vat is furnished with agitators at the bottom, to keep the pulp of an equal thickness, which now bears a strong resemblance to curdled milk.

From the vat or stuff-chest, the pulp, prepared as already described, is let out by a sluice into a pipe, which leads it to one end of the *making-machine*.

The machine now in general use for the making of paper is the invention of Louis Robert, a Frenchman, and was brought to this country about eighty years ago by a M. Didot, who, with the assistance of M. Fourdrinier, and Mr Donkin, the engineer, greatly improved the invention, and obtained a patent for it. The machine has since been improved by numerous manufacturers, and fig. 24 is an excellent representation of one of the most perfect and modern, made by Mr George Bertram of Edinburgh, who has done very much to perfect the machinery. This machine combines the strainer for preventing knots entering with the pulp, invented by Ibbetson, and the sizing and calendering machinery, so that the paper comes out ready for cutting into sheets.

The first part of the machinery upon which the pulp comes is a brass wire-cloth, which is woven in the same way as linen, and is of so fine a texture that there are seventy wires in the inch. This wire-cloth may be described as a sort of belt without any break, which is kept continually

revolving, but in such a way that the upper side, upon which the stuff is received, preserves a flat and horizontal surface. The wire-cloth moves upon a number of small copper rollers, which have an agitating horizontal motion, and this distributes the stuff equally over the cloth, giving a uniform strength and thickness to the paper. After passing between a pair of rollers, where it delivers the stuff, it is led backwards again under the frame; and so goes on in a continuous revolution. Movable sides are attached to the upper surface of the wire, which regulate the breadth of the sheet to be manufactured.

The first pair of rollers through which the stuff passes are called the couching-rollers. The under roller is simply cast-iron, while the upper one is covered with woollen cloth of a peculiar texture, manufactured for the purpose. It is upon this upper one that the stuff is delivered. The pressure from these rollers is slight; and the pulp is next led on to an endless web of felt, and passes between two cast-iron rollers. The machinery of this felt must be so regulated that it will go with the same speed as the wire-cloth and couching-rollers, otherwise confusion would ensue. In passing through the first pair of rollers, only one side of the stuff is rendered smooth; but in the second pair it is reversed, and the rough side is now pressed. These rollers are closer than the first pair, and the pressure being greater, the sheet is now more dry and firm.

The sheet next passes through two other pair of rollers, which press out the water, and render the paper smooth and firm. It is then carried to the drying-cylinders, which are hollow, and filled with steam, introduced by pipes placed at both ends of their axes. The paper is again passed through a pair of rollers, to smooth it after being dried, and is then wound upon a reel. As one reel is filled, it is taken off, and another put on in its place; and it is evident that the paper can be made of any length the reel is large enough to hold. Thus, at one end is seen running in a stream of liquid resembling curdled milk, and at the other comes out a finished fabric, the time required for manufacturing thirty feet of which is little more than a minute.

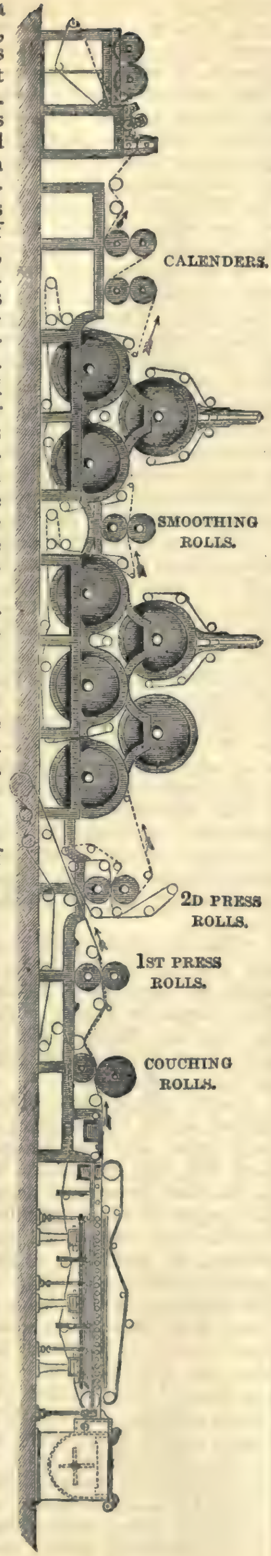


Fig. 24.

The material used formerly was almost entirely linen rags; subsequently, rags of cotton were introduced, but produced inferior paper. Now, an enormous quantity of a species of grass is used; it is called Esparto and Alfa. The former name is applied to that imported from Spain, the latter to that from the north of Africa. Its botanical name is *Lygeum Sparteum*.

CAOUTCHOUC.

This remarkable substance is now so largely used in connection with textile fabrics, that a notice of its properties and applications may not be uninstructive to the reader.

Caoutchouc was first seen in Europe about the middle of the 18th century. It was then brought from Guiana and other provinces on the eastern coast of South America, and, from its valuable power of cleaning paper, was called *India-rubber*. It is the produce of several tropical trees, amongst which *Siphonia elastica* yields the chief part of the South American; and various species of Ficus the East Indian and African. The mode of obtaining it is simple: In the cooler seasons of the year, incisions are made around the tree, completely through the bark; and the milky juice which exudes is either immediately applied to moulds of unburned clay, or collected in vessels. If applied to moulds, it is dried, layer by layer, over a fire made by burning the seeds of a species of palm, till of the desired thickness. The applications of caoutchouc to useful purposes are very numerous; but our remarks must be confined to the water-proof garments well known by the name of Mackintoshes—from the name of the inventor—they are formed of fabrics covered on one side with the caoutchouc; or two fabrics are joined by a thin layer between them. To obtain the material in the thin sheet required, it is heated and kneaded by powerful machinery until it is thoroughly softened without being liquefied; it is then spread upon the cloth by means of a flattening mill.

By the important process of vulcanising India-rubber, it has its utility greatly increased, and is made to exhibit such properties, that it may be said 'to form a new substance.' This condition can be produced by kneading the India-rubber with sulphur, and then exposing it to a temperature of 190° Fahrenheit.

By combining caoutchouc with sulphur at a higher temperature, Mr Goodyear has imparted to it the hardness and rigidity of wood, but at the same time a plasticity which enables it to be produced in a variety of forms: this is now generally termed vulcanite.

DECORATIVE DESIGN AS APPLIED TO TEXTILE MANUFACTURES.

Linen damask, as used for table-cloths and napkins, receives its ornament from a peculiar distribution of the threads in the weaving, surface-printing being rarely if ever applied to linen. In the application of ornament to this fabric, the designer should aim at flatness of treatment, avoiding all subjects in which relief is required. This excludes representations of architectural relieved ornaments, fruit, and indeed all subjects perspectively treated. The design for a table-cloth naturally divides itself into two parts—the centre space, and the border. In the border, or that portion which falls over the edge of the table, the lines should be flowing, while the centre space may be filled up with a diaper arrangement of geometrical figures, or conventionalised floral or natural forms well distributed.

Cotton.—The ornamentation of cotton fabrics is almost exclusively effected by surface-printing. The two great classes of ornamented cottons are *garment* and *furniture* fabrics. As colour is used very much in these fabrics, the designer must view the ornamentation he is desirous to carry out in a twofold aspect—form and colour.

True symmetry of form can only be obtained by a geometrical distribution. That 'ornament has a geometrical distribution, and is subject to symmetry and a correspondence of parts,' will be easily seen on considering that, in the words of Mr Redgrave, 'it is not possible to cover a large space with a repetition of small ornaments without *some* symmetrical arrangement developing itself.' And wherever the eye has a difficulty in tracing this symmetrical arrangement, it may be at once concluded that the treatment is unsatisfactory; it will, in fact, be wanting in the essential character of 'repose.' The character of the ornamentation should also be attended to—leaves, sprigs, flowers, and simple scrolls being most suitable, and these, of course, treated flatly, avoiding all relief and perspective. Small forms will also be in better taste than large. The 'making up' and the 'nature' of the material have also to be observed. With reference to the nature of the material, the designer should remember that it has certain peculiarities which should not be lost sight of; that cotton, for instance, has not the surface lustre of silk, and that patterns applicable to the latter will, if applied to the former, display a want of truth. Again, cotton is a material easily cleaned; in fact, its most pleasing peculiarity is this idea of purity it conveys. Unlike wool, therefore, which partakes of opposite qualities, the pattern should be so arranged that a large portion of the surface be left in its natural condition.

The following is given by Mr Redgrave as an enumeration of the principles which should regulate the application of design to garment fabrics. 'The ornament is always flat and without shadow; natural flowers are never used imitatively or perspectively, but are conventionalised by being displayed flat, and according to a symmetrical arrangement; and all other objects, even animals and birds, when used as ornament, are reduced to their simplest flat form. When colour is added, it is usually rendered by the simple local hue, often bordered with a darker shade of the colour, to give it a clearer expression; but the shades of the flower are rarely introduced.' It is worthy of note, that the fabrics in which those principles were applied in the Great Exhibition of 1851, were those exhibited by the East India Company. They shewed 'how much beauty may be obtained by simple means when regulated by just principles; and how perfectly unnecessary are the multiplied tints by which modern designers think to give value to their works, but which increase the difficulties of production out of all proportion to any effect resulting from them; nay, even to the absolute disadvantage of the fabric.'

In the treatment of *furniture fabrics*, many of the suggestions we have already given will be applicable. The prevailing aim has hitherto been to have large decided figures, giving ample scope for the display of gay and striking colours. Hence have originated vulgar gaudy patterns, in which obtrusiveness and want of *design*—using the term in its most significant sense—have been the chief characteristics. The symmetrical arrangement of a simple ornament with flat treatment, as already described, will be found much more pleasing than the absurd patterns too frequently used.

Silk and Woollen Fabrics.—The principles we have already indicated for the decoration of cotton, will be applicable in great measure to these; attention, however, must be paid to the nature of the material. Thus the beautiful peculiarity of silk, its brilliant lustre, must not be hid by any over-colouring or a redundancy of ornament; this, of course, does not refer to self-coloured silk, or to brocades where the ornament is of the same lustre as the body of the material. Again, the nature of wool admits of a greater redundancy of ornament, and a larger amount of colour.

The following we give, in conclusion, as the principles applicable to printed garments. 'The ornament should cover the surface, either by a diaper based on some regular geometrical figure, or growing out of itself by graceful flowing curves.

'The *size of the pattern* should be regulated by the material for which the design is intended—small for close thick fabrics, such as ginghams, &c.; larger for fabrics of more open texture, such as muslins, Bareges, &c.; largely covering the ground on de laines, and more dispersed on cotton or linen goods.'

Carpet Decoration.—The main idea which a carpet should convey is an easy natural surface to walk upon, and not obtrusive—that is, it should look flat, and its colours should be 'subordinate to the more prominent pieces of furniture.' Hence all carpets in which huge flowers or floral subjects, architectural ornaments, and the forms of living objects, are portrayed in high relief and with perspective effect, and which 'challenge attention by the brilliancy of their hues in masses, or the tortuosity of the lines in the boundaries of their forms,' are considered to be in bad taste; and hence, also, the principles which dictate flat forms, without shadow or relief, and well distributed over the whole surface. As regards colour, all violent contrasts should be avoided, and 'graduated shades of the same colour, or a distribution of colours nearly equal in scale of light and dark, should be adopted; secondaries and tertiaries, or neutralised primaries, being used rather than pure tints, and lights introduced merely to give expression to the form.'

USEFUL MINERALS.

STRICTLY speaking, a mineral is an inorganic body with a more or less definite chemical composition, and having a regular geometric form in which it crystallises. This, at least, is the case with the great majority of minerals. A mass of rock may be composed either of one or of several minerals; thus, quartz rock is formed of the single mineral quartz, and granite rock is formed of the three minerals, quartz, felspar, and mica. There is, therefore, a distinction between the terms 'rock' and 'mineral;' but we shall here use the latter term in the wider sense in which it includes all inorganic substances—that is, all substances except those derived from the vegetable and animal kingdoms. Only the non-metallic minerals, however, or what are usually classed as such, will be treated of in this sheet, metallic ores and metals forming the subject of a separate number. On account of extensive discoveries in new localities of many valuable minerals, of the profitable applications of some formerly regarded as useless, and of the possible exhaustion before long, in this country at least, of others, such as coal, mineral products have, for the last twenty years, been gradually acquiring an interest and importance greater than they ever possessed at any former period.

The various kinds of rock, and the way in which they occur in the crust of the earth, are described in the number on GEOLOGY; but we may here briefly state what the three principal classes of them are: 1*st*, We have *aqueous, sedimentary*, or *stratified* rocks, which have been deposited under water, and lie in parallel beds or strata. These include, among others, sandstones, limestones, coal, and shale. 2*d*, *Igneous* or *unstratified* rocks, which are of volcanic origin, and have no true bedding. Of these, lava, basalt, dolerite, and porphyry are examples. And 3*d*, *Metamorphic* rocks, which may either be of aqueous or igneous origin, but whose former condition has been changed by heat and chemical action. Such rocks as gneiss, mica-schist, serpentine, and some granites are of this class. The sedimentary series are the only rocks that contain the remains of plants and animals, called *fossils*, which are of great importance in determining the geological age of the different groups of strata termed *formations*. All three divisions of rocks are found traversed by veins and lodes of sparry minerals and metallic ores; while other minerals, such as coal and clay-band ironstone, are only found in stratified formations, and are themselves real beds of sedimentary rock.

BITUMINOUS SUBSTANCES.

Under this head, we shall take the more important natural bitumens, such as asphalt, petroleum, and naphtha; but it is well to state that the varieties of this substance are numerous, and all are valuable as sources of light and heat. They consist essentially of carbon and hydrogen; burn in the open air with a highly smoky flame; and are probably the result of the action of subterranean heat on coal or lignite. In this section, too, we shall include coal, lignite, jet, bituminous shale, and other allied bodies; because, although bitumen does not appear to exist in them ready formed, yet, on being distilled in close vessels, they yield products similar to the native bitumens. Such minerals are more properly called bituminiferous than bituminous. The word bitumen is from a Greek term signifying the pitch-tree.

Coal.—No product of the mineral kingdom is of greater importance to man than coal. Its value as a fuel appears to have been long known, since the researches of archæologists shew that it was highly probable the Romans, when they occupied Britain, were not unacquainted with its use, coal-cinders having been found as part of the relics of a few Roman stations. Coal was, at all events, known during the Anglo-Saxon period, and employed to some extent as an article of household consumption as early as 852 A.D. In 1259, the first public document respecting this mineral appears. It is in the form of a charter by Henry III. granting liberty to the freemen of Newcastle-on-Tyne to dig for coals. Soon after this, a considerable export trade in what was then, and long after, called 'sea-coal' was established with London; but, as has been the case with many natural products when first introduced, a strong prejudice sprung up against it in the metropolis. The outcry about the injurious influence of its smoke on public health at length became so general, that, in 1306, Edward I. issued a proclamation forbidding its use. Under the pressure of a decreasing supply of wood, however, its use in London was in a few years resumed. In Scotland, coal was worked in Fife and the Lothians as early as the fifteenth century, and in Ireland not later than the beginning of the sixteenth. From the time of Elizabeth, the coal-trade has been regarded as one of national importance, and since then has continued to flourish, although in the time of Charles I. it was heavily burdened with taxation. In all the large towns of the United Kingdom, coal has been burned since towards the middle of the seventeenth century; and before the close of the last century, the extension of canals in the English manufacturing counties greatly increased its consumption there; but until the great extension of the railway system in 1845-50, large districts were practically unable to get it on account of the cost of conveyance. The introduction of Watt's steam-engine, however, in 1769, and more especially the rapid extension of its use in manufactures and navigation, during the present century, has contributed more than anything else to increase the demand for coal, and has, moreover, enabled the miner to supply that demand, by the new facilities it afforded him for raising this fuel from great depths and over extensive areas. Since the introduction of gas-lighting, too, in 1810, a very considerable quantity of coal has been consumed at home, as well as exported to other

countries, for the manufacture of gas. The following statistics will shew how remarkable has been the increase in the produce of coal in Britain since 1750, but it must be borne in mind that it was not till 1854 that the coal statistics of the country were carefully collected:

		Tons.
Coal raised in	1750	5,000,000
" "	1800	10,000,000
" "	1816	27,000,000
" "	1855	64,307,459
" "	1870	110,431,192
" "	1884	160,757,779

Before giving the extent of our British coal-fields, we shall first state how coal is believed to have been formed, and what the leading kinds of it are. True coal is scarcely obtained from any other geological formation than that of the Carboniferous or coal-measures, where it occurs interstratified with sandstone, shale, fire-clay, limestone, ironstone, and other substances, the whole formation being one of remarkable economic importance. Coal-seams vary in thickness from a few inches up to thirty feet, the latter, however, being rather an aggregate of several seams from which intervening material has been washed away.

Coal is undoubtedly formed of vegetable matter; its chemical composition, its microscopic structure, and the abundant remains of plants in it, all prove this. The exact process by which it has been formed has not been so clearly ascertained; nevertheless, in the opinion of most geologists, our coal-seams are composed of plants which grew *in situ* on the underclays always found immediately beneath them. This is so far evident, from the fact that the trunks of trees, called *sigillaria*, occurring in the coal, have been found in some instances actually connected with their roots, termed *stigmaria*, in the underclay beneath it. As these underclays are all stratified, they must have been formed under water; and it is supposed they were once the bottoms of shallow marshes, estuaries, or lagoons, on which, under favourable conditions of climate, a vegetation grew more rank and luxuriant than that of any other geological period before or since. By the constant decay and renewal of forests on the same site, and perhaps by the drifting of plants from other areas, carried thither by currents, a great mass of vegetable matter would at length accumulate. The conversion of this into coal was no doubt effected by the slow subsidence of the soil on which the plants grew, and the accumulation of overlying strata, which would in course of time produce an amount of pressure sufficient, along with chemical changes, to mineralise the pulpy vegetable matter into a bed of true coal. There seems to have been, during the time of the coal-formation, not only a great luxuriance of vegetable growth, fostered by a peculiarly humid and equable climate, but a singularly regular subsidence of the land, accompanied by pauses of long duration. These conditions occurred at no other period of the earth's history, and they were singularly favourable to the production of coal, because, although this mineral does occur in other formations, such as the Oolite, it is always in comparatively small quantity and of inferior value.

The various kinds of coal may be broadly divided into three—namely, 1. Cannel or Parrot Coal; 2. Common or Household Coal; and 3. Anthracite. The first includes those coals which are believed to have been formed from decomposing vegetable matter in water, in a fine state of division, which have little or no lustre, and which, being highly bituminous, yield a large quantity of gas or paraffine oil, according as they are distilled at a high or a low red-heat. The second kind includes many sub-varieties, as caking coal, cherry coal, smithy coal, splint coal, all of which are bituminous, but less so than cannel coal. Some of them, however, are regularly used for making gas. Caking coal *cakes* or fuses together when burning; cherry coal is soft, and breaks into small cubes, and, like most of the varieties of bituminous coal, except cannel, it has a resinous or shining lustre. Splint coal is hard and slaty, and, when of good quality, gives off great heat in burning. The third kind, anthracite, is coal which has had almost all its volatile or bituminous matter driven off by contact with igneous rocks. It is therefore nearly pure carbon, has a high and sometimes iridescent lustre, and is difficult to kindle, but when once ignited gives out intense heat. It is chiefly used for smelting ore and for raising steam.

The coal-measures of Great Britain are supposed to have been originally continuous with those of France and Belgium, and to have once spread over a much wider area in Britain itself than they now do. Disturbance, denudation, and the deposition of newer strata, have combined to limit our accessible coal-fields to those areas which they now occupy. As the productiveness and probable duration of these were not long since made the subject of a searching inquiry by a Royal Commission, we shall best give an idea of the extent of each, by quoting the following table from its first Report, published in 1871:

QUANTITIES OF AVAILABLE COAL IN THE CHIEF BRITISH COAL-FIELDS, AT DEPTHS NOT EXCEEDING 4000 FEET, AND IN SEAMS NOT LESS THAN ONE FOOT THICK, AS GIVEN IN THE REPORT OF THE COAL COMMISSIONERS, DATED 1871, IN STATUTE TONS.

South Wales	32,456,208,913
Midland (Yorkshire, Derbyshire, and Nottinghamshire)	18,172,071,433
Northumberland and Durham	10,036,660,236
Lancashire and Cheshire	5,546,000,000
Bristol	4,218,970,762
North Staffordshire	3,825,488,105
South Staffordshire, Coalbrookdale, and Forest of Wyre	1,906,119,768
North Wales	2,005,000,000
Smaller English coal-fields	2,041,620,251
Total of Scottish coal-fields	9,843,465,930
Total of Irish coal-fields	155,680,000
Grand total, tons,	90,207,285,398

The Scottish coal-fields lie in an irregular belt, stretching across the country in a north-east direction, from the coast of Ayrshire to that of Fife, with an average breadth of twenty-five miles.

In Ireland, as the above table shews, the quantity of workable coal is very limited, and consists chiefly of anthracite; nevertheless, at one period of the earth's history, not less than two-thirds of the country must have been covered by coal-beds, which have been subsequently swept away by denudation.

Some of the coal included in the foregoing table exists under the Permian rocks, a formation which immediately overlies the coal-measures; but there

is probably, besides this ascertained quantity, a considerable extent of sub-Permian coal-seams not yet proved. It appears, too, that, in the opinion of many eminent geologists, coal is not unlikely to be found at depths not exceeding 1200 feet, under the chalk and other newer formations in the south of England—coal-seams having been found under these strata across the Channel, not far from Calais.

Taking into account the coal which probably exists under the Permian, New Red Sandstone, and other superincumbent strata in the United Kingdom, the coal commissioners increase their estimate of the quantity still available for use to 146,480 millions of tons. In 1881 Dr Hull corrected the figures to date, giving a total available supply of 136,000 million tons, sufficient, in his estimate, to last for a thousand years (the coal harvest of 1880 being 147,000,000 tons). On the other hand, some authorities assert that, owing to increase in population, and the increasing consumption of coal in manufactures, about 100 years will suffice to exhaust them. Between this and the other extreme of about 1000 years, formed on the assumption that hereafter the population of the country will but slightly increase, there are innumerable conjectures and estimates.

On the continent of Europe, productive coal-fields occur in Belgium, France, various parts of Northern Germany, Spain, and Russia. By far the largest in area are those of Russia, and they are known to contain many valuable beds of coal, although as yet comparatively little has been worked. Coal is also found in India, China, Japan, and the Malayan Archipelago, in Australia and New Zealand, and in Africa. Turning to the New World, there is evidence of promising coal-deposits in several South American countries, but, owing to the great supply of wood in their forests, there is little temptation to work them. In Canada, Nova Scotia, New Brunswick, and Newfoundland, there are small, though valuable coal-fields; but, in the United States, by far the largest fields of fossil fuel in the world are found. The entire area of these is about 200,000 square miles, being 38 times greater than the area of the coal-fields of Great Britain. But although the coal-measures of the States are of vast extent, and contain many valuable coal-seams—a few of them 40 and even 50 feet thick at certain places—it has been doubted by some shrewd observers whether the amount of workable coal in them is not greatly exaggerated by American writers. In proportion to the extent of the seams, the quantity of coal annually raised in the States is small, being only about 70,000,000 tons.

In what has been already said, no notice has been taken of fuel found in formations other than the coal-measures. True coal, however, occurs in the Oolite at Brora in Sutherland, in Skye, Yorkshire, and Pennsylvania, and that found in Australia appears to belong to formations both older and newer than the Carboniferous. Nor should we omit to mention a substance called brown coal or lignite, of which large deposits occur in the Wealden, Chalk, Eocene, and Miocene of North Germany, Austria, and Italy. This mineral, which often retains its woody structure in a nearly perfect state, is of less value than true coal, but still it is of great importance as a fuel to the districts where it is found. A few years ago, about 5,000,000 tons of it were raised in one year in Prussia alone.

Coal-mining is in some districts a comparatively simple operation; but in regions where the strata are troubled, where fire-damp is prevalent, and where the workings are deep, much care and skill are required in conducting it. A seam of coal scarcely ever lies in a horizontal position—it is nearly always inclined, and sometimes at a very high angle. Suppose, then, we were to begin to work a coal-seam from the 'outcrop' downwards, we could not take it out to any great depth without being stopped by the accumulation of water; and on account of this difficulty, no attempt was made, in the early days of coal-mining, to work deeper than could be done in the fashion of an open quarry. Next came the plan of driving in a tunnel, called a *day-level*, from the lowest point, on, say, a sloping hill-side, till it reached the coal-seam. This served as a drain, and allowed all the coal above that level to be worked out. In later times, and in situations where a day-level was not practicable, an inclined tunnel or gallery was sometimes made, with wooden lift-pumps at certain distances to remove the water. Sometimes, again, it was removed in barrels wound up vertical shafts 30 or 40 fathoms deep. Coal was brought to the surface by methods equally primitive. Some pits were fitted with ladders, up which women carried the coal on their backs in baskets, and this, too, occasionally from a depth of 50 or 60 fathoms. In other places, boys, and women as well, drew it in small four-wheeled trams along sloping galleries to the surface, or along levels to the bottom of a shaft, to be hoisted by a windlass in tubs to the mouth of the pit.

By successive steps from these rude modes of mining, some of them here and there still in use, we come to the method practised at the present day in many of the larger English collieries. A few of these are noble specimens of underground engineering. The shaft is sunk—in more than one instance at a cost of nearly one hundred thousand pounds—to the lowest point of the coal-seam which can be practically reached; and this is in some cases about two thousand feet deep. From the bottom of this, galleries, called *levels*, are driven in several directions, sometimes one or even two miles in length. These have just enough of rise to allow water to flow back to the *sump* or lodgment at the bottom of the shaft, into which the pumps dip. From the levels, other roads are driven in different directions, and if the seam is thin, say under four feet, then the whole of the coal is removed as the colliers proceed. This is called the *long-wall* system. If it is thick, then pillars or stoops are left at regular distances, and between them the coal is worked out. In this way, the ground-plan of a mine becomes not unlike that of a forest with thick square dumpy pillars instead of round trees. This is variously called the *post-and-stall*, *board-and-pillar*, and *stoop-and-room* system. A large and powerful steam-engine is, of course, required to raise the coal from such depths, and to pump out the water which rapidly accumulates in all underground operations. One of these engines will raise a cage loaded with thirty-six hundredweight of coal, fourteen hundred feet in a minute, bringing to the surface about a thousand tons a day.

The proper ventilation of a coal-mine is a

matter of great importance, although it has been somewhat simplified since the Act of 1863, which requires that there must be two shafts to every colliery. Fresh air not only requires to be supplied to all the workings, but it must be forced through the passages with a sufficient current to sweep away all noxious gases. Of these, light carburetted hydrogen or fire-damp, and carbonic acid or choke-damp, are the most dangerous. The former forms an explosive mixture in certain proportions with air, and is the great cause of explosions in coal-mines. Wherever it occurs in any quantity—for it is not present in all coal-seams—safety-lamps must be used by the miners; of these there are several kinds, but it will be sufficient to notice the one invented by Sir Humphry Davy in 1816. This is simply an oil lamp inclosed in a cylinder of wire-gauze containing from six hundred to eight hundred holes to the square inch—seven hundred and eighty-four being fixed upon as the standard. Fire-damp passes freely through the apertures, so that when the lamp is held in a fiery atmosphere, the gas inside the cylinder takes fire, but, on account of the cooling action of the wire-gauze, the flame cannot kindle the fire-damp outside, unless it is blown through with considerable force. Great care is required to keep the Davy lamp in good repair, because the slightest injury may destroy its safety; yet the experience of half a century has proved that, when used with proper caution, it is practically safe in the most explosive atmospheres. Its feeble light, however, often tempts the more reckless miners to remove the wire-gauze, or to work with other naked lights, even in the presence of fire-damp, and hence the cause of many a dreadful accident.

Safety-Lamp.

The duration of our coal-supplies depends greatly on the depth to which it is possible to carry mining operations. As already stated, two thousand feet has been reached in the north of England; and in Belgium, coal is being worked at the depth of two thousand eight hundred feet. Indeed, in that country, one shaft has been sunk to over three thousand feet. The expense of sinking shafts to these depths, however, is so great that a considerable rise in the price of fuel will probably take place before they are sunk much deeper. At three thousand feet below the surface, the temperature is known to be at 98° F., or blood heat, and at this high temperature, labour for more than short intervals is not practicable, where, as in a coal-mine, the air is always more or less moist. Still, many practical men consider that by more effective ventilation, and possibly also by other means of artificially cooling the air, a depth of four thousand feet will ultimately be reached. Of course, if it should ever be possible to penetrate to still greater depths, the areas of our available coal-seams will be greatly extended.

Within the last twenty years, some costly litigations have taken place in Edinburgh, London, Prussia, and Canada about two minerals, in regard to which the question was whether they were or were not coal. One of the substances in dispute was the Boghead cannel coal or Torbanehill mineral, found at Bathgate, and now nearly exhausted, which yields so much gas or mineral oil on distillation, that a few years ago it sold as high as four pounds sterling per ton. The other was the mineral called Albert coal or Albertite, found in New Brunswick, a beautiful, glossy, jet-like substance, also very rich in the hydrocarbons which form gas or burning oil. With regard to the first, the one side asserted that it was a true coal; the other, that it was a bituminous shale, because, although it yielded products like coal, yet, unlike most coals, it had a dull earthy look, and a very high percentage of ash. As respects the Albertite, the issue was whether it was coal or asphaltum, those who held the latter view founding chiefly on the fact, that its geological position was that of a vein, and not that of a bed or stratum. In these trials, which were very protracted and enormously expensive, great numbers of scientific and practical men were engaged on both sides. Their object, however, was quite as much to decide with reference to the nature of a bargain, as to make out a precise definition of coal. Sometimes the verdict was one way, sometimes the other; and on the whole, as has been well remarked, these trials have only succeeded in shewing that no suitable definition of coal exists, and that there will always be differences of opinion when the substance to be determined approaches the boundary of the shales and of the bitumens.

Bituminous Shale.—In several geological formations, but chiefly in the Carboniferous, there exist extensive beds of shale so highly bituminous that mineral oil for burning and lubricating, as well as paraffine, can now be profitably distilled from them, indeed more profitably than from even the richest cannel coal. It is, remarkable to say, not more than fifteen or sixteen years since these very shales were looked upon as among the most worthless of sedimentary strata. Nothing, in fact, in the history of mineral industries, is more striking than the suddenness with which a new process, chemical or mechanical, will sometimes convert a waste or useless material into one of great value, by extracting from it products of much utility or beauty. These oil shales, as they are now called, can sometimes be advantageously distilled when they do not yield more than twenty-five gallons of crude oil per ton; but they not unfrequently yield as much as fifty gallons, and between these there are all degrees of richness. In Great Britain there are now about twelve million gallons of burning oil annually produced, for which about seven hundred and fifty thousand tons of shale are required. As those who have most experience in the matter believe that the cost of the distilling apparatus at present in use will eventually be greatly lessened, it is highly probable that much poorer shales will sooner or later come into use. But even the richer shales extend over an area of very many square miles; and as the workable seams vary in thickness from three to six feet, the quantity of light and heat giving material, still stored up in our coal-measures, apart altogether from coal itself, amounts to millions of tons. The intrinsic value of it, too, is, roundly speaking, about one-half that of coal.

Naphtha—Petroleum—Asphalt.—Bitumen, although not a very exact term, is convenient as a

specific name to include several combustible substances, the most important of which are naphtha, petroleum, and asphalt or mineral pitch, all closely resembling each other in chemical composition. They are found both as liquids and solids. The latter are dissolved by the former, and are also soluble in alcohol. They consist essentially of carbon and hydrogen, but a little oxygen is also present in the harder kinds of asphalt. From a light limpid naphtha at one extreme, to a hard rocky asphalt at the other, these bitumens possess all degrees of consistency.

The terms naphtha, petroleum, and rock-oil, as now used, are vague and perplexing. When applied to native products, they all really mean the same thing. If there is any difference, naphtha is only a lighter kind of petroleum, but sometimes the one name, sometimes the other, is applied to the very same substance. With artificial products such as the oils or liquid hydrocarbons distilled from coal, those with the lowest specific gravity are called naphthas, to distinguish them from the heavier bodies of the same kind, such as paraffine or burning oil, dead oil, &c. So, also, when crude native petroleum is purified, the lighter hydrocarbons obtained in the distillation are called naphthas, and the heavier ones petroleum, kerosene, &c. There is this important distinction in these cases, that the lighter hydrocarbons or 'naphthas' are more dangerous than the heavier. The former can be burned with safety in lamps of a peculiar construction, but not so in ordinary petroleum or paraffine-oil lamps. The vapour of these light bodies takes fire at, or even under, 100° F., and they cannot be safely used in ordinary lamps if their firing-point is below 120° F.

The petroleums or naphthas which have been longest employed for lamp-oils and other useful purposes are those found in Persia, in the Burmese empire, on the shores of the Caspian Sea, and in different parts of Italy. Most of these are easily purified, and have then a pleasant odour, a rare property among mineral oils. Considerable quantities have been imported into England from Baku and Rangoon, and, but for their high price, these would soon supersede all other rock-oils in the market. The great Pitch Lake of Trinidad, about three miles in circumference—from which the lamp-oil called 'kerosene' was first obtained—the petroleum springs and bitumen mines of Cuba, and the oil-springs of the United States, have also been long known as yielding valuable bituminous products. But these substances, from several causes, have attracted so much attention of late years, that new supplies of them have been discovered in various parts of South America, in Canada, Siberia, and other countries.

Of all the known sources of petroleum, by far the most important is the coal region of the United States. Several of the localities where it is found were known to the Indians, by whom it was at one time collected for sale; but it is little more than twenty years since the oil-wells were sunk deep enough to give any considerable yield. In a very few years the trade grew with astonishing rapidity, for the shipments, which, in 1861, were only 1,500,000 gallons, amounted in 1871 to 155,613,000 gallons. It is estimated that the world's consumption of illuminating oil amounts to 1,800,000 gallons every day. The import of petroleum into the United Kingdom in 1884 was 52,975,789 gallons, of the value of £1,711,313, of which 50,200,956 gallons came from America. The total shipments of refined oil from America in 1885 amounted to 6,985,637 barrels, of which the United Kingdom received 1,269,723, London taking 666,964 barrels. The production of mineral oil from shale in Scotland, in 1885, was about 55,000,000 gallons of crude oil.

Besides being burned in lamps, naphtha is used as a solvent for india-rubber, as a cheap substitute for turpentine, in the manufacture of lamp-black for printers' ink, and some kinds of it for the production of benzole, now so largely required in the manufacture of aniline colours.

Asphalt, or mineral pitch, is the name given to a compact form of bitumen, which is usually black or dark-brown in colour. When free from earthy impurities, it has a conchoidal fracture and resinous lustre. Asphalt is generally found wherever rock-oil occurs, and in such localities it is clearly produced by the drying up of the petroleum. In many places, however, it occurs in veins or beds forming a compact rock. The Dead Sea, some of the West Indian Islands, and one or two places near the borders of France and Switzerland, are the best known localities for this substance; but it is found, less or more, in a great many countries. Asphalt was employed by the ancient Egyptians for embalming their dead, and it is said to have been used in Babylon as an ingredient in mortar. Its modern applications are numerous. It is an ingredient in Japan varnish, and is used along with other materials to make water-proof roofing and flooring, linings for cisterns, and in the construction of water-pipes. It is much used now to form what are called 'damp courses' in walls—that is, a layer of it about two inches thick is spread over the thickness of a wall near the ground-level, to prevent the ascent of damp. One or two kinds, such as those found at Seyssel in the east of France, and at Val-de-Travers in Switzerland—which, however, are rather bituminous limestones than true asphalts—have, since 1854, been very extensively employed in the construction of foot and carriage pavements in Paris, and also, within the last two years, in some of the busy parts of London. When this material is used, there is, of course, far less noise produced by the traffic on the streets than with stone. Pavements formed of an artificial or coal-tar asphalt have long been, to a limited extent, in use; but they have never been liked, on account of their liability to soften with the heat of summer.

Jet.—Some cannel coals which do not change when exposed to the atmosphere, and which take on a fair polish, are made, in the localities where they are found, into bracelets, inkstands, vases, and even tables. Others, again, although they have much the same appearance at first, are totally unfit for such purposes, as they are soon decomposed by the action of the atmosphere. In Philadelphia, boxes and small ornaments are made of anthracite.

The beautiful black substance jet, which, like coal, is merely fossilised wood, is found in small quantities in the Lias beds of Yorkshire, the pieces varying from an ounce to two hundredweight in weight. It likewise occurs along with amber in the lignite beds of Germany, in Aude and other departments of France, as well as in several other

countries. In the middle ages, it was, and in Prussia is still, called black amber. Jet was valued by the Romans chiefly for its medicinal qualities, although they also made ornaments of it. Its lightness, toughness, and the beautiful polish which it takes, render it peculiarly suitable for cutting into bracelets, brooches, ear-rings, and other objects which are largely worn as mourning jewellery. The jet district of Yorkshire is around Whitby, and there and at Scarborough, the centres of the trade, the annual value of the articles made of it is upwards of £125,000. Good imitations of jet are now made from hardened india-rubber called 'vulcanite,' but they are apt to turn gray. Those made of black glass are easily known by their vitreous glare. Perhaps the best are obtained from a material called *bois durci*, a peculiar composition of charred sawdust and other ingredients.

Amber.—Amber is a fossil resin found in several countries, but in marketable quantities only on the coast of the Baltic between Königsberg and Memel. It is said to claim the highest antiquity among minerals used for personal ornament, and to be the only one known to the early Greeks. It was carved into elegant forms by the Etruscans, and maintained its high value among the Romans long after they obtained it in large quantities from the Baltic. Amber ornaments are less esteemed now than of old, probably on account of their softness and brittleness; yet the finer pieces of this substance are still prized for beads, brooches, necklaces, and like articles, and also for the mouth-pieces of pipes. It is found both transparent and opaque, from a pale primrose to a deep golden orange—the transparent kind, which is the more common, having a high refractive power. Amber is largely used in the manufacture of varnishes, but the greater portion of it is sent to China for burning as incense. The largest piece known weighs eighteen pounds, and is in the Royal Museum at Berlin. Some specimens contain extinct species of insects, and even small fish, which must have been entombed when it exuded as a soft gum from trees.

CALCAREOUS SUBSTANCES.

The familiar substance limestone, when pure, consists of the elements of calcium oxide and carbonic acid, and is called calcium carbonate, or carbonate of lime. Calcium occurs largely in nature combined with other substances. Thus, besides limestone, marble, and chalk, which are identical in chemical composition, we have gypsum or alabaster, formed of calcium oxide and sulphuric acid; apatite, formed of calcium oxide and phosphoric acid; fluorspar, formed of calcium and fluoric acid; and so on. These and other compounds of calcium are called calcareous bodies. Limestone of various kinds forms by far the most abundant of these, and is chiefly of organic origin. Chalk, for example, usually consists of more than ninety per cent. of the cases of Foraminifera and comminuted shells; coral rock, of the calcareous skeletons of compound animals allied to the sea-anemones; and common limestone, of the shells of molluscous animals. In some situations, the same bed of rock can be seen passing gradually from a dark limestone, full of fossil shells, to a white crystalline marble, with all trace of fossils obliterated by metamorphic action. Some limestones, however, have been formed by the precipitation of carbonate of lime from calcareous waters.

Common Limestone.—Few substances are of greater economic importance than common limestone, and it is fortunately abundant in one form or other through all the geological formations, from the oldest to the newest. Most countries, accordingly, have extensive and widely distributed deposits of this material. Limestones vary much in their texture, being soft and earthy, like some chalks; concretionary, as in oolitic roe-stones; hard and compact, or crystalline, as they pass into the state of marble. Besides these and other kinds of simple limestones, there are also composite varieties, as magnesian, silicious, argillaceous, arenaceous, bituminous, conglomerate, and hydraulic limestones. Limestone is usually obtained by working it in open quarries, but sometimes it is worked downwards by a rude kind of mining. When it is wanted for such purposes as the preparing of mortar, cements, or plaster, it requires to be heated in a kiln, so as to convert it into what is called *lime-shell*, *quicklime*, or *caustic lime.* In this process, the carbonic acid is driven off by the heat, and what remains is oxide of calcium or lime. The kiln is a stone building, square, round, or oval in shape, in which layers of limestone and coal are laid alternately, so that the latter may effectually calcine the limestone. If limestone is underburned, it retains some carbonic acid; if overburned, it combines with silicic acid; and in neither case will it slake well. Quicklime is *slaked* or converted into hydrate of lime by sprinkling it freely with water, and is then mixed with sand when made into mortar. Hydrate of lime is soluble in water to some extent, but, curiously enough, more so in cold than in hot water. Lime-water thus obtained is used for several chemical and pharmaceutical purposes.

The uses of lime are so numerous, that we can only mention a few of its principal applications. Some of these have already been referred to, but it is also an indispensable ingredient in the manufacture of bleaching-powder, soda, soap, candles, glass, nitre; in the preparation of leather; as a flux in metallurgy; in the purification of coal-gas; in agriculture, as a reclaimer of peaty soils, and in liberating alkali from such as consist of clay. Some limestones, especially those from the oolitic formation, furnish valuable building-stones. Like many sandstones, these cut with equal freedom in any direction—all building-stones with this property being called free-stones. Of these oolitic limestones, the best known are Portland stone, used in the construction of St Paul's Cathedral and other London buildings; Bath stone, also employed in the metropolis; and the beautiful French stone from Caen.

Marble.—The term marble is frequently applied to serpentine, alabaster, porphyry, and other stones which take a polish, and are used in a similar way to marble for decorative purposes. True marble, however, is merely a limestone sufficiently hard and compact to take on a fine polish. British marbles are usually obtained from the older or palæozoic rocks, and chiefly from the Carboniferous and Devonian strata; but they also here and there occur in the newer formations.

In England, Derbyshire, Staffordshire, and Devonshire are richest in useful marbles. Their colours are white, gray, dove, blue, black, and red more or less mixed; and according to the peculiar way they are marked with fossils, they are known as bird's-eye, entrochal or encrinital, dog-tooth, shelly, and breccia marbles. Many of the Devonshire specimens are wholly formed of fossil corals, and are called madrepore marbles. Ireland is peculiarly rich both in pure and in what is known as serpentinous marble. The latter, which is often of great beauty—the green Connemara marble, for example—is an intimate mixture of serpentine and limestone. The famous Italian *verd-antique* is also a rock of this kind. Black and coloured marbles occur in Kilkenny, Carlow, Galway, Mayo, and several other localities. In Scotland, there is a beautiful pink marble, dotted over with dark green spots, found in the island of Tiree. Marbles also occur in Skye and Jura, on the mainland of Argyllshire, and in Sutherlandshire.

In most foreign countries there are marbles more or less valuable; some, indeed, as Italy and Spain, have them in such profusion, that the supply is almost inexhaustible, and the wealth of colour and pattern endless. The best of the Italian marbles are those of the Apuan Alps, which rise around Carrara, Massa, and Seravezza. The beautiful white saccharoid marble from the Carrara quarries is now used by sculptors all over the world. Of this material, about seventeen thousand cubic feet, amounting in value to nearly thirty thousand pounds, are annually exported; but this is a mere bagatelle compared to the quantity of inferior marbles exported yearly from this district for architectural and furniture purposes, which amounts to forty millions of cubic feet. One third of this goes to America, one third to England and France, and the remainder to other European countries. The beautifully coloured and variegated marbles found here and elsewhere in Italy are chiefly consumed in the country. Some of the finest of these are nearly twice as valuable as the best statuary marble. The most famous of the marbles used by the ancient Greeks were those of Paros and Pentelicus, both white marbles. We have not space to say anything about the marble trade of other countries, few of which export to any extent. Of late years, however, considerable quantities of Belgian slabs have found a market in England on account of their cheapness. Extensive and valuable beds of white and other marbles are found in the United States and Canada.

Some marbles are so peculiar in their nature as to receive special names. Among such are the beautiful Algerian *onyx marble*, which is a stalagmitic carbonate of lime; the *fire marble* of Carinthia, which has a rich play of deep red and other colours; and the *ruin* or *landscape marble* found at Bristol, the figuring of which, when polished, looks like a representation of ruins.

Being slightly soluble in water, and especially in carbonic acid water, marble is unfitted for external work in most European countries. But some varieties, such as the brecciated Italian marbles, which are formed of calcareous fragments united by a silicio-calcareous cement, and have also an admixture of hornblendic substance, resist the decomposing action of the atmosphere, and retain their polish for years.

Marble is cut into blocks or slabs by thin plates of soft iron set in a frame, and driven by a steam-engine. Sand and water are at the same time freely supplied to the cutting irons, whose motion is exactly that of an ordinary saw. Mouldings are formed with cutting tools shaped to the required form. Columns, vases, and balusters are first rudely chiselled to a round shape by hand, and then turned on a lathe, a process which leaves fine ridges on the object. These, as well as the saw-marks of flat surfaces, are rubbed down with sand and water, and finally a polish is brought up on the marble with fine emery and putty powder (oxide of tin). Granite, serpentine, alabaster, and other ornamental stones are cut and polished in a similar way.

Chalk.—As already stated, chalk is of the same chemical composition as limestone, of which it is merely a variety. It forms the last of the secondary or mesozoic rocks, and is largely represented in the south and south-east of England. Chalk, although usually too soft, is yet employed in some districts to a considerable extent as a building-stone. It is largely used to prepare lime for mortar, cements, and artificial stone. When purified, it yields whiting or Spanish white; and the finer kinds of it are of great service in schools for writing on black-boards. Drawing-chalks are not composed of this material, but of various others, according to their colour. Thus, red chalk is a peroxide of iron; black chalk is a kind of clay, coloured with carbon; and French chalk, used for marking metal, is a silicate of magnesia.

Magnesian Limestone—Magnesia.—Dolomite or magnesian limestone forms a large portion of the upper strata of Permian rocks, as developed in Yorkshire and other parts of England, and in Germany. It occurs also in other countries and in other formations. Dolomite is usually crystallised either in large or small granules; but it is very variable in its lithological character, being either compact, earthy, friable, concretionary, or in thin laminations. Its most common colour is buff yellow, but it is also found of various other tints. Magnesian limestone is used for agricultural and other purposes much in the same way as ordinary limestone. It is, however, a much more valuable building-stone, especially when it is of homogeneous texture, and contains the carbonates of lime and magnesia (calcium and magnesium carbonates) in nearly equivalent proportions. But it stands best, and will even endure well for centuries, in a country atmosphere. In large towns, it appears to be unable to resist the corroding action of the atmosphere, which usually contains a minute quantity of mineral acid. The Houses of Parliament are built of dolomite, chiefly from Bolsover Moor, in Derbyshire; and although the main portion of this costly structure is only a quarter of a century old, it already shews such unmistakable signs of decay, that silicious solutions of various kinds are being tried to preserve the rich carving.

In a typical magnesian limestone, nearly a half of its bulk consists of magnesium carbonate—that is, the metal magnesium in union with oxygen and carbon. In the neighbourhood of Newcastle, Epsom salts (magnesium sulphate) are made from dolomite, by treating it with sulphuric acid; and in the same district, carbonate of magnesium, also used in pharmacy, is obtained

from it by a process invented by the late Mr H. L. Pattinson, in which the calcined material is submitted to the action of carbonic acid and water under pressure. On account of the diminished use of them in medicine, Epsom salts are now made in much less quantities than in former years. Some dolomites are used as lithographic stones, but the best of these are obtained from the oolitic limestone of Solenhofen, in the Bavarian Jura.

Marl—Calcareous Sand.—In several geological formations, what are called marl deposits occur. The term marl is properly applied to clay with a variable admixture—from 10 to 70 per cent.—of lime; but sometimes a mixture of clay and sand is called marl. *Shell-marl* is formed by the decomposition of fresh-water shells, mixed to some extent with clay or earthy matter, and is found at the bottom of old lakes. Most marls form remarkably fertile soils, and when the proportion of lime in them is considerable, they are useful manures, a property which has been known from very early times. *Calcareous sand* is formed of fragments of shells or coral, more or less mixed with silicious sand or other substances.

Gypsum — Alabaster. — Gypsum, or calcium sulphate, is a highly useful mineral, found abundantly in England and many other countries, especially in the New Red Marls. Near Paris, it is found in the Tertiary deposits. There are several varieties of this substance known by different names: when colourless, transparent, and crystallised, it is called *selenite*, when finely granular and translucent, it is known as *alabaster*, or if fibrous, as *satin spar*. The plainer masses of gypsum are calcined to produce plaster of Paris or stucco, a material extensively used in the arts and manufactures.

The finer kinds of alabaster are used as ornamental stones, the working of which, like that of marbles, forms an important industry in Italy, where they occur extremely pure and compact at Volterra and La Castellina, in Tuscany. These are largely made into statues, vases, timepiece stands, and other works of art, in Florence. The alabaster found in Derbyshire and Staffordshire is also used for ornamental purposes, but chiefly for objects of a small size. Alabaster is more soluble in water than marble, and, therefore, is even less fitted for external work. Some alabaster can hardly be distinguished from marble by the eye, but it is much softer. What is called oriental alabaster is a stalagmitic carbonate of lime.

When gypsum is cautiously heated to about 500° F., it forms an artificial anhydrite, well known in commerce as plaster of Paris or stucco. The calcined gypsum can then be formed into a cream or paste with water, which after a short time solidifies or *sets*, and is soon reconverted into gypsum. This property makes plaster of Paris a substance of great value in making moulds for, or taking casts of, objects of art or utility. The greatest consumption of it in Great Britain is for making the moulds used in the manufacture of pottery; but it is also much used for internal architectural ornaments, in the preparation of cements and artificial marbles (scagliola), in the hardening of some kinds of paper, and for many other purposes. Fictile ivory is plaster of Paris soaked in wax, spermaceti, or stearine. The total annual consumption of gypsum in Great Britain is supposed to be about 30,000 tons, and its value about £10,000.

Apatite—Phosphate of Lime.—Apatite or native calcium phosphate has now become a mineral of considerable importance in the preparation of artificial manure. It is imported in shiploads for that purpose from Krageroe in Norway. A still more valuable deposit of it, called *sombrerite*, is found in the small island of Sombrero in the West Indies. The organic remains, called coprolites, also extensively used for manure, consist for the most part of calcium phosphate. In Spain, some massive and marble-like varieties of apatite are used as building-stones.

Coral.—In our number on ZOOLOGY are noticed those compound zoophytes which secrete or in some way produce reef, precious, and other kinds of coral. Reef coral is a calcium carbonate, occasionally forming large islands in the Pacific and Indian Oceans, as well as long fringing reefs which extend along the coasts of countries washed by these seas. One of these barrier reefs, on the north-east coast of Australia, extends in a continuous line to a length of about 350 miles. The polypes which construct these coral rocks are never found living at a greater depth than 180 feet, so that, when the reef is thicker than that, either some subsidence or some upheaval has taken place with the rock on which the coral structure rests. This kind of coral is sometimes used as a building-stone, and in the preparation of lime.

Madrepore Coral (*Madrepora plantaginea*).

The beautiful substance red coral is the calcareous axis of the compound zoophite, *Corallium rubrum*, and is obtained almost entirely from the Mediterranean. The principal fisheries are on the African coasts, and at present it is the Italians and Maltese who are chiefly engaged in it. Nets and iron drags are used in obtaining the coral, which is often brought up from depths reaching to about 800 feet. From at least Pliny's time to the present day, the great market for coral has been India and other Eastern countries, where it is held in great estimation by the natives for ornaments of various kinds. Even their dead are frequently adorned with coral, to preserve them from evil spirits. The Romans used this material

Coral, shewing the polypes (*Corallium rubrum*).

as an amulet and in medicine; the Gauls, largely for decorating their arms; and in the middle ages jewels were frequently set with it. In Europe the demand for coral is now only moderate, but the annual value of what is sent to the East is estimated at £200,000. The cutting and working of it are extensively carried on in Naples, Leghorn, Genoa, and Marseille.

ARGILLACEOUS SUBSTANCES.

It will be convenient to group under this head all the substances in which clay (*argilla*) is the predominating ingredient. From the brick and boulder clays of the most recent deposits, through all the formations, down to the oldest, argillaceous compounds of one kind or another occur. These include substances varying much in texture and appearance, as plastic clay, fire-clay, shale, and the clay-slate used for roofing. Plastic clays are chiefly confined to the recent formations; while clay-slate, clay-stone, and argillaceous shale no doubt represent the clays of the older geological periods. Typical clay is an aluminium silicate (silicate of alumina); but ordinary clay is usually that substance in combination with some alkaline silicate. Alumina, which is the base of clay, is the oxide of the metal aluminium. See the sheet on METALLURGY.

Clay.—Clay suitable for being made into common bricks, tiles, or coarse earthenware, is an abundant material, but such clay is always mixed with impurities, the principal of which are sand, lime, magnesia, and oxide of iron. Common clay, when fired, is either red or buff in colour, owing to the presence of iron. The fine pottery clays which burn white will be noticed presently. Fire-clay, from which highly infusible furnace-bricks, gas-retorts, crucibles, and the like, are made, is found in the coal-measures, in alluvial deposits, and in other formations. A good fire-clay consists of aluminium silicate, with little or no lime, alkali, or iron, as these substances give it fusibility. The Stourbridge fire-clay bricks and crucibles are so famous for their refractory nature, that this clay is exported to the most distant parts of the world. But for high and long-continued heats there are still more refractory bricks made from the Dinas rock in the Vale of Neath, South Wales. This substance, however, can scarcely be called a clay, as it is nearly all silica.

Fine plastic clays which are pure enough to burn white in the kiln are valuable substances. Such clays form the chief part of the raw material required for the manufacture of pottery and porcelain, so largely carried on in Staffordshire and many other parts of Great Britain. The leading kinds are pipe-clay, China clay, and Bovey clay. *Pipe-clay* is tough, very plastic, of various colours in the raw state, and consists of little else than silica, alumina, and water. It is chiefly obtained in Dorsetshire from the Bagshot beds of the Middle Eocene, and, from its being shipped at Poole, is sometimes known as Poole clay. From that port, 67,579 tons were shipped in 1870 to various parts of the country, but principally for use in Staffordshire and London, in making earthenware and stoneware. Much of it, however, is also employed in the manufacture of tobacco-pipes, for domestic purposes, and by modellers. *China clay* or kaolin, so largely used as an ingredient for the body of fine porcelain, is the most valuable of all clays. It occurs in sufficient quantity and purity for manufacturing purposes in but few places—Aue, near Schneeberg in Saxony, Gomritz below Halle, St Yrieix in France, and Cornwall in England, being the best known European localities. It appears to be found largely in China and Japan. Kaolin is no doubt everywhere a product of decomposing rocks rich in felspar. In Cornwall, it is obtained by washing the decomposing felspar of granite, but some of it occurs in deposits which have accumulated by the action of rain. The composition of kaolin is the same as pipe-clay, with the addition of small quantities of calcium and magnesium silicates, and of free silica. It forms a plastic mass with water, and when dried and fired, remains unmelted at an intense white heat. China clay is the chief ingredient required for the manufacture of porcelain, has of late been largely used in paper-mills, and has also been recently applied in the figuring of wall-papers. It is likewise employed in some places in the manufacture of alum. In 1870, the produce of China clay in Cornwall and Devonshire was one hundred and twenty-three thousand tons, valued at more than a hundred thousand pounds, the greater part of which was prepared at St Austell and its neighbourhood. *Bovey clay*, also a product of decomposing granite, is obtained from Bovey-Heathfield, Devonshire, and, like other white clays, is extensively used by potters. Above forty-eight thousand tons were shipped from Teignmouth in 1870. We may here add that the decomposing granite itself, under the name of China stone or Cornish stone, is also much used in the potteries. The total produce of china clay, china stone, and potter's clay in Cornwall and Devon in 1884, amounted to 357,283 tons, valued at £263,576.

Fullers' Earth.—This substance is a soft, unctuous, fusible clay or earth, which has the power of removing grease or oil from wool. Formerly, it was used in the woollen districts for 'fulling,' but soap has now superseded it.

Ochre.—This term should perhaps be confined to a clay coloured by hydrated oxide of iron, but it is often applied to any earth containing iron, or more rarely other substances, such as chromium or uranium, which can be used as a pigment. Ochre is obtained near Oxford, in Cornwall, in the east of Fife, and several other places; also in other countries. The ochres of especial interest to the painter, however, are those of Siena in Italy, which are found of yellow, brown, and red colours. The colours prepared from this substance are of remarkable stability, as may be well seen in many pictures by the old masters. There is a very pretty way of decorating the interior of houses practised in India, by means of coloured earths and clays, which is worth mentioning here. Instead of merely smearing the floor and wall with pipe-clay and ochre, as we do, the natives, by means of hollow wooden rollers, perforated with various patterns, and filled with earths of different colours, produce various designs on such surfaces. This is quickly done, and can therefore be easily renewed whenever the pattern becomes soiled.

Clay-slate.—The rocks which yield the best roofing-slate are the Cambrian and Silurian, although some is also obtained from the Devonian and Old Red Sandstone. Clay-slate is a highly

indurated argillaceous rock, and consists, like ordinary clay, principally of silica and alumina, with varying proportions of oxide of iron, and potash, soda, or magnesia. It has originally been deposited as fine muddy sediment, which has not only been afterwards hardened by metamorphic action, but the direction in which it splits has been changed by great lateral pressure. That is to say, slaty rocks do not, like most sedimentary strata, split in the planes of stratification, but at every possible angle to these, by what is called the 'natural split' or 'cleavage.' It is this fissile structure, along with fine texture, which gives slate its peculiar value. The most extensive slate quarries in the British Islands are those of Penrhyn, Llanberris, and Festiniog, in North Wales. In this district, about 350,000 tons of slates are annually produced, the value of which is estimated at £700,000. At Borrowdale, in Cumberland, and at Easdale and Ballahulish, in Argyllshire, there are also large slate quarries, as well as lesser ones about Dunkeld and many other localities.

Since the repeal of the duty on slates carried coastways, in 1831, this material has received many new applications. For roofing purposes, the Scotch slates are stronger but coarser looking than the Welsh. Sometimes, however, the latter are used for public buildings in very large thick slabs, in which case they are very strong. In the neighbourhood of some slate quarries, the walls of houses are built of the more compact portions of the rock. Slate is also used in thick slabs for pavement, for shelves, and extensively now in the construction of tanks and cisterns. These larger pieces, after they are quarried, are sawn and polished by ordinary stone-cutting machinery; but common-sized roofing slates are split by hand with a mallet and broad steel chisel, and dressed with a knife. This material has of late years been applied to the production of what is called 'enamelled slate,' a purpose for which it is singularly well adapted. School slates and pencils are made from fine-grained slate.

SILICIOUS SUBSTANCES.

Silica or silicic oxide is one of the most abundant ingredients in the crust of the globe. Quartz, or rock-crystal, is an example of pure silica; and agate, chalcedony, flint, and sandstone are composed of little else than this substance. Silica is the oxide of silicon or silicium, and is a feeble acid.

Rock-crystal—Quartz.—Transparent quartz is called rock-crystal, a material of much use for some purposes, yet not of much intrinsic value, unless it happen to be finely crystallised or possess attractive colours, as in the varieties called amethyst and Cairngorm stones. Clear and colourless rock-crystal, when in large pieces and free of flaws, is cut by the Chinese and others into hollow cups and vases, and also by the Japanese into very perfect spheres. These, from the amount of labour required to work so hard a substance, are very costly, but they are objects of great beauty. As rock-crystal is harder as well as cooler than glass, it is better adapted for the lenses of spectacles and opera-glasses, a purpose for which it is now a good deal used. Opaque quartz is an abundant substance, of little value. Aventurine is a quartz filled with golden-coloured scales, probably of mica.

Flint.—Common flint is found in nodules of various sizes, occupying distinct layers, chiefly in the Upper Chalk. The nodules are usually quite separate, and surrounded with chalk; sometimes, however, flint is found in flat tabular layers. Silicious bodies, resembling the chalk-flints, are found in other limestone rocks, and are probably due to the same origin. Different authors have accounted in various ways for the formation of flints, but all that has been certainly ascertained is that, in almost all cases, they are silicified sponges. This has been proved by Dr Bowerbank. Flint is nearly pure silica coloured dull amber, gray, or black, by some organic substance which disappears on calcination, leaving a white mass of silica. This property gives flint a peculiar value for white pottery, in the manufacture of which it receives its chief application. It was formerly used in making crystal, hence the name 'flint' glass. In the chalk districts it is employed as a building-stone and road-metal. Before the introduction of lucifer-matches, flint was in universal demand for striking fire with steel, and its use for this purpose on guns is not even yet obsolete—those sent to the interior of Africa being usually supplied with them. In prehistoric times, it was the chief material of which cutting implements were made. Flint is slightly harder than quartz, and has a characteristic conchoidal fracture.

Sandstones.—Sandstone, as well as limestone, when it cuts freely in any direction, is called freestone. Any rock which is formed of sand compacted firmly together is a sandstone, or sometimes, if it is very coarse, a gritstone. Usually, the particles of which it is composed are water-rolled grains of quartz, and according to the colour of these, we have stone of endless shades of colour, from a nearly pure white to a decided black, including yellow, brown, red, gray, and green. It is the glistening nature of the quartz particles which gives sandstone its peculiar beauty, as contrasted with ordinary limestone. In large towns, one can sometimes scarcely tell a limestone front from one done in cement; but this is never the case with a sandstone. Particles of various minerals, such as mica, felspar, oxide of iron, lime, or clay, are frequently disseminated through sandstones, and according as one or other prevails, we have micaceous, felspathic, calcareous, argillaceous, or ferruginous sandstone. The durability of a sandstone depends much upon the nature of the substance which cements the grains together—if silicious, the stone is more likely to be lasting than if it is calcareous, but hardly any test except long experience can be trusted to determine whether a building-stone is durable or not. Sandstones differ much in hardness, but many of the softer kinds harden when exposed to the atmosphere.

In England, good sandstone for building purposes is comparatively rare, that found at Darley Dale in Derbyshire, and at the quarries about Mansfield in Nottinghamshire, being exceptionally good. In Scotland, on the other hand, it is most abundant, all the principal towns being built of sandstone, either from the Carboniferous or Old Red Sandstone formations, with the exception of Aberdeen, which is chiefly of granite. Craigleith Quarry, near Edinburgh, produces one of the best

building-stones anywhere found, but its comparative hardness renders it costly to work. Binny Quarry, near Linlithgow, has furnished the stone for the finest buildings erected in Edinburgh of late years. The flagstones from the Old Red Sandstone of Forfarshire and Caithness, especially the former, are largely employed for foot-pavements. Some of the Yorkshire flagstones are also extensively used for pavement and like purposes. The *millstone-grit* of Northumberland and adjoining counties furnishes grindstones. A curious flexible sandstone is found not far from Delhi, in India, examples of which may be seen in most of our public museums.

Sand.—Sand, in the great majority of instances, is composed of grains of quartz more or less pure; sometimes, however, it is formed of fragments of shells, or coral, and more rarely of particles of iron ore, and even of gems. As is the case with clay, the most valuable kind of silicious sand is that which is either white or will burn white. This variety is highly prized for making the finer kinds of glass, and is found at Alum Bay in the Isle of Wight, and a few other localities. For glass-making, it is first washed and calcined. Some kinds of sand are specially adapted for making the moulds used by founders for casting metal objects. The commoner sorts are in request for the making of mortar, in causewaying, in the manufacture of coarse glass, and for many other purposes.

Granite.—For reasons we have not space to state, many geologists are now of opinion that granite is, in some cases, a metamorphic rock, although in others it must be regarded as a truly igneous rock, which has invaded sedimentary strata in a fluid or semi-fluid state. A typical granite consists of quartz, felspar, and mica; and a typical gneiss, of the same three minerals arranged differently—namely, in irregular layers. Syenite is a granite where the mica is replaced by hornblende. Some granites contain additional minerals, such as schorl, while others termed two-grained contain only quartz and felspar. Granite is one of the most prevalent of rocks all over the world, and forms the great bulk of many mountain chains.

Of English granites, those of Cornwall and Devonshire are the best known, and they are extensively used in London and other places in the construction of bridges, embankments, and architectural works. In one year forty thousand tons, valued at £75,000, have been shipped from Cornwall. Granite is also obtained in Westmoreland and in Leicestershire. In Scotland, this rock is largely quarried at Dalbeattie in Kirkcudbrightshire, in the Ross of Mull, and in Aberdeenshire. The beautiful red and blue granites found near Peterhead are now extensively worked, by cutting and polishing machinery, in Aberdeen, into columns, pedestals, fountains, tombstones, and other objects. Many of these, as well as much of the gray granite paving-stone of Aberdeen, are sent to London. Some jewellery is also made of Scotch granite. There is some good granite found in Ireland; indeed, the most extensive range of it in the British Islands extends S.S.W. of Dublin for seventy miles. The great monolith called Pompey's Pillar, at Alexandria, one hundred feet high, and ten feet in diameter, is of red granite, and so also is the external casing of many of the Pyramids. The colour of granite, as well as its durability, depends chiefly on the felspar. Some kinds of it are the most enduring; some, again, as, for example, the decomposing granite of Cornwall, are among the most perishable of rocks. A striking example of its lasting nature may be seen in the façade of the Carlton Club in London, erected in 1847. Here the polish on the columns of red Peterhead granite is quite undimmed, while the limestone mouldings are fast crumbling away.

Serpentine—Meerschaum—Talc.—These are magnesium silicates. *Serpentine* is a metamorphic rock, found in several localities in the British Islands, but most largely worked in Cornwall. It is perhaps the most beautiful of all our native ornamental stones. Its most prevalent colour is dark green, but, like marble, which it much resembles, it occurs of many colours and of various patterns, indeed rarely without veins, blotches, or mottling. Although comparatively soft, it takes on a beautiful polish, and is much more durable for external work than marble. Of late years it has been extensively used in England, both externally and internally, for decorative architecture. *Meerschaum*, resembling serpentine in composition, is found in Asia Minor and a few other places. The name signifies 'foam of the sea,' from its lightness and white colour. Its chief use is in the manufacture of tobacco-pipes, large numbers of which are made in Germany. *Talc* is another hydrous silicate pretty generally diffused. *Steatite*, or *soapstone*, is another mineral of the same class, and *agalmatolite*, yet another, with potash and alumina instead of magnesia. This last is much used by the Chinese for carving into grotesque figures. Steatite, being very refractory, is sawn into slabs for lining furnaces and stoves; in Germany, it is made into gas-burners. It is used to give translucency to porcelain, as a polishing material, and for several other purposes. *Potstone*, or *lapis ollaris*, is an impure talc, made into culinary vessels in Lombardy.

Mica—Asbestos—Jade—Lapis Lazuli.—These are anhydrous silicates of various bases, but chiefly of magnesia. *Mica*, one of the component parts of granite, occurs of several varieties, but it is only when it is found in large thin transparent plates that it is used in the arts. It is not easily acted on by heat, and is consequently used for lanterns and the doors of stoves. *Asbestos* is a fibrous variety of hornblende, which can be woven into an incombustible cloth. Fabrics made of it were used by the ancients to wrap up the bodies of the dead about to be burned. *Jade*, *nephrite*, or *axe-stone*, is a beautiful, hard, translucent mineral, found of several colours, but the best known are leek-green and white. The finest white pieces are said, and perhaps truly, to be valued by the Chinese at more than their weight in gold. At anyrate, some beautifully carved vases, cups, and like objects brought from China, have sold of late years at very high prices in England. In New Zealand and Western America, the green variety is carved into images and fanciful objects, and also, on account of its hardness, formed into axes. *Lapis lazuli*, or *azure-stone*, is a silicate of aluminium, sodium, and calcium, with smaller quantities of other substances. It is of a rich azure-blue colour, often mottled with gold-like spangles, and has been long prized as an ornamental stone. It

is found in Siberia, near Lake Baikal, in China, Persia, and India. Lapis lazuli is highly esteemed for costly vases, for inlaying, and for mosaics. It is also used to some extent in jewellery. When powdered and washed, it furnishes ultramarine blue, the most beautiful, durable, and costly of all colours. Its price is five guineas per ounce. One of the triumphs of modern chemistry has been the production of an almost perfect imitation of this splendid colour, which, under the name of French or artificial ultramarine, is now consumed in vast quantities as a pigment and colouring material.

Basalt — Greenstone — Felstone. — These substances, and many similar ones, are often classed under the general name of trap-rocks; that is, all those rocks that are not distinctly granitic or of recent volcanic origin. The nomenclature of igneous rocks, however, is at present in a very unsettled state. Greenstone and basalt are now rather applied to groups of rocks than to individual kinds. The various felspars, hornblende, augite, and quartz are the minerals of which these igneous rocks are chiefly formed. Chemically, they are either magnesium or aluminium silicates, in both cases mixed with smaller quantities of other silicates. Industrially, they are extensively used for causewaying, macadamising, and, where other stone is scarce, in building houses.

Volcanic Products.—The products of recent volcanoes are not only interesting geologically, but the chief ones, as lava, obsidian, and pumice, are also useful. *Lava*, when compact enough, is employed for building, and in Iceland, such things as hand-mills for grinding corn and coffee are made of it. In Naples, lava of a peculiar texture from Vesuvius is largely made into cameos and other ornaments. *Obsidian* is a volcanic glass often quite undistinguishable from ordinary black bottle-glass; but sometimes it is prettily figured, and such varieties are made into boxes and ornaments. The natives of some countries make rude hatchets and knives of common obsidian. *Pumice* or *pumice-stone* is a light, porous, hard, and brittle substance. It is really the same material as obsidian or trachyte, ejected from volcanoes in an extremely vesicular instead of a compact state. Large quantities are exported from the Lipari Islands and other localities to different countries, as a polishing material for metals, marble, ivory, hard wood, and for smoothing parchment and some kinds of leather. *Pozzuolana* is a loosely coherent volcanic sand much used in the preparation of hydraulic mortar.

Polishing Slate, or Tripoli, &c.—Tripoli is an earthy silica or a sandy variety of quartz mixed with clay, found in various countries. It usually consists of the cases or skeletons of Diatomaceæ and Infusoria, and each individual being invisible to the naked eye, the effect of the substance, when used for polishing, is only to produce fine invisible scratches. Tripoli is used to polish metals, marble, optical glass, and gems. *Rottenstone* is a soft, earthy stone, supposed to be derived from the decomposition of a silicious limestone or shale. It is found in Derbyshire and South Wales, and near New York, but hardly anywhere else. When reduced to powder, it is employed for polishing the softer metals and alloys, as silver, brass, Britannia metal, and also glass.

SALINE SUBSTANCES.

We have grouped under this head, along with common salt, such substances as alum, nitre, natron, and borax, which in chemical language are called salts. They all occur native, but some of them are prepared on a large scale artificially from mineral substances which yield them. Those we describe are of great and indispensable service in various manufactures, and in the case of common salt for culinary purposes as well.

Rock-salt—Common Salt.—Common salt is a compound of the metal sodium with the gas chlorine, hence it is also called the chloride of sodium—its old name being muriate of soda. The supply of this substance is inexhaustible, as sea-water contains it in the proportion of nearly four ounces to the gallon. It also exists in the water of salt lakes, and in many countries it is obtained from brine springs, and in the solid form as rock-salt. Sometimes rock-salt is found so pure and white as to require nothing but grinding, but more frequently it is mixed with clay, bitumen, and other foreign matters, from which it requires to be purified. It occurs transparent and colourless; also white or some shade of yellow, red, blue, or purple. Very impure kinds are often dirty gray. Rock-salt is found crystallised in cubes, the finer specimens of which are objects of great beauty.

Formerly, a great deal of salt was obtained by evaporating sea-water in shallow iron pans, but in this country the process is now almost entirely abandoned, although still practised in some parts of Europe.

Rock-salt and salt springs—the great source of common salt commercially—occur in many countries, and in almost all geological formations. In England, beds of rock-salt are worked in Cheshire, and brine springs both there and in Worcestershire. In 1863, a bed of rock-salt one hundred feet thick was discovered at a depth of thirteen hundred feet at Middlesborough-on-Tees. On the continent of Europe there are vast deposits of rock-salt: in Spain, where, in the valley of Cardona, it forms hills from three hundred to four hundred feet high; in Poland at Wieliczka, near Cracow, where the mines are perhaps the most ancient and celebrated in the world; in several of the Austrian provinces, Prussian Saxony, Switzerland, France, and in Southern Russia. It occurs in Asiatic Russia, Persia, China, and India, where, in the Lahore district, it forms large hills. Northern Africa, as well as both North and South America, also contains abundant supplies of salt, either as rock-salt or in salt lakes and brine springs.

In the Cheshire salt-mines, the beds of rock-salt occur in the New Red Sandstone associated with marl and gypsum, and vary in thickness from six inches to nearly forty feet. They are worked at a depth of from fifty to one hundred and eighty yards below the surface, where the salt is mined much in the same way as coal, shale, or any other mineral occurring in strata. The shafts are usually square and lined with timber, and are employed for the usual purpose of raising the produce of the mine, the ascent or descent of the miners, ventilation, &c. Gunpowder is used to blast the rock, the ordinary mining tools being employed for boring and removing the loosened

masses. A steam-engine is, of course, required to work the winding apparatus and pumps. In some of the mines, the pillars left to support the roof are twenty to thirty feet square, and they are generally at regular distances apart, so that when a deep working is in full operation and lighted up with candles, the effect is striking and brilliant. Far more salt is, however, obtained in Cheshire and elsewhere from brine springs than from the rock-salt beds. The pumps used to raise the brine are placed in shafts lined with clay puddle, to prevent the access of fresh water.

As many as 1,250,000 tons of salt were produced in Cheshire in 1870, rather more than one-tenth of which was rock-salt. In the same year, the yield in Worcestershire was 220,000 tons, and in the Belfast district, 9162 tons.

In India, the excise-duty imposed upon salt is a considerable source of revenue, yielding in some years £7,000,000. There, indeed, the production of salt is practically a government monopoly. This is the case also in Austria, where the annual produce is about one-third that of Great Britain.

Under what circumstances rock-salt has been deposited has not yet been satisfactorily explained. Probably the theory most in favour is, that it was deposited in salt lakes which had no outlet, so that in the course of time, as the water flowing into the lake would be more or less saline, and that which evaporated pure, more salt would accumulate than the water could hold in solution. A deposit of salt would then take place, and eventually become covered by the sediment which now forms beds of marl and other strata.

Alum.—Alum is a sulphate of aluminium and potassium, or the sulphate of potassium may be replaced by the sulphates of ammonium, sodium, or magnesium, or several other substances. According to its composition, therefore, alum is distinguished as sodium-alum, ammonium-alum, potassium-alum, and so on. The last two are, however, the common kinds. Several of these alums occur native, but only in small quantities, so that, for use in the arts, it is artificially prepared from alum-stone, alum-shale, some coal-measure shales, and pure clay. The best alum is made from the alum-stone of Tolfa, near Rome. Immense quantities of ammonium-alum are now made at Manchester, by treating the common shale of the coal-measures with sulphuric acid and then adding ammonia, obtained from gas liquor. Potassium-alum is also largely made from a similar shale near Glasgow, as well as from a Lias shale at Whitby. Potassium and ammonium alum are equally serviceable in the arts.

Pure China clay, or pipeclay, treated with sulphuric acid, and ammonia or potash added, yields an alum easily purified, but the high price of these clays makes it unprofitable to use them.

A sulphate of aluminium, under the name of *concentrated alum*, is manufactured in considerable quantities by treating pure clay with sulphuric acid, ferrocyanide of potassium being used to purify it from iron. It is used by dyers instead of common alum.

Ordinary alum has a sweetish, astringent taste. It is soluble in cold water to the extent of about five parts in one hundred, but at the boiling-point one hundred parts of water will dissolve about four hundred and twenty parts of alum. This substance is extensively used in many manufactures, but especially as a mordant or fixing agent in calico-printing. It is also used to prepare the colours called *lakes*. With it white leather is tanned or tawed, and tallow is hardened. In medicine it is used as an astringent; and after wood or paper has been well soaked in it, neither will easily take fire.

Potassium Nitrate (*Nitrate of Potash*).—This salt is known in commerce as *saltpetre*, and sometimes as *nitre*, although the latter term is also applied to the sodium nitrate. Potassium nitrate is composed of potassium oxide and nitric acid. It is an important and valuable substance, from its being an indispensable ingredient in the manufacture of gunpowder. The principal supply of saltpetre is derived from India, whence we import annually some 200,000 hundredweight. Considerable quantities are also obtained in Arabia, Persia, Spain, and Hungary. In these, and, indeed, in most warm countries, it occurs as an efflorescence on the soil, but it does not penetrate to any depth. This saltpetre earth is merely lixiviated, and from the solution so obtained the salt crystallises.

Of late years, considerable quantities of saltpetre have been made by treating the native nitrate of soda, 'Chili saltpetre' (a more abundant salt), with carbonate of potassium. In this way carbonate of sodium is precipitated and removed, and a solution of potassium nitrate remains. Besides its use in making gunpowder, saltpetre is employed in fireworks, in medicine, and in curing meat. It is the sal-prunella of the shops.

Sodium Nitrate (*Nitrate of Soda*).—There are various names given to this salt, but those chiefly in use are *cubic nitre*, *cubic saltpetre*, and *Chili saltpetre*. It crystallises in rhombohedrons, while potassium nitrate crystallises in six-sided prisms. Sodium nitrate occurs in enormous quantity in the district of Tarapaca, Northern Chili, where it is found in beds several feet thick. It is largely consumed in the manufacture of nitric acid and as a manure for grass land.

Natron—Trona.—Two native sodium carbonates are found, one called *natron*, or the hydrated carbonate, and the other termed *trona*, or the sesquicarbonate. The second contains more soda than the first, and it is also harder and less deliquescent. Natron occurs abundantly in the soda lakes of Egypt and Trona, not far from Fezzan, and in Barbary. In some parts of India, considerable tracts of land are rendered quite sterile by an efflorescence of carbonate, but more frequently of sulphate of soda, on the soil.

Borax.—Borax, or sodium borate, is a compound of the elementary substance boron, the gas oxygen, and the metal sodium. It is also called *tincal*, and is obtained in large quantities in the valley of Pugá, Ladakh district, Northern India, and in Tibet. In Pugá, the borax-producing locality is under the influence of thermal springs, and the mineral is found in deposits of two or three inches in thickness, lying immediately below an efflorescence of salts of soda. It is transported across the Himalaya on the backs of sheep and goats, and refined at Jagādri, Amritsir, and other places, by simply dissolving it in water, and then evaporating the solution till crystals of borax form. Of this mineral, whose important uses will

be presently noticed, 21,161 hundredweight (valued at £52,953) were imported into England from India in 1869. Borax is also prepared from a mineral called hayesine, which is a native calcium borate scattered over dry plains in southern Peru.

In the volcanic districts of Tuscany, a native boracic, or, as it is sometimes called, boric acid, is obtained from the water of boiling springs which issue from the ground in the form of jets of steam, called *soffioni*. From this borax is formed by the addition of sodium carbonate. These are directed into lagoons or artificial basins, which are scattered over a surface of about thirty miles, and are constantly giving off clouds of smoke, the district being subject to constant shocks produced by subterranean agencies. These basins are constructed of coarse masonry, each large enough to contain a few soffioni, and six or eight of them are placed at different levels on the hill-side. Into the uppermost basin the hot springs are allowed to flow; and after remaining twenty-four hours, during which time the water is kept in constant agitation by subterranean vapour, it passes by means of a pipe into the next lower basin. Here it remains another twenty-four hours, and, of course, takes up an additional quantity of boracic acid. In this way, the water passes through each successive basin, till, in the last, it contains about 0·5 per cent. of boracic acid. This weak solution is then evaporated in long leaden tanks placed low down in the ground, and ingeniously heated with steam produced by subterranean heat. This method was first applied by Count Larderel in 1817, and has had the effect of converting, although slowly, an unprofitable branch of industry into the most important chemical manufacture of Italy. The concentrated solution of boracic acid is finally crystallised in tubs, and then spread out on the floor of a hot chamber to dry. The product thus obtained is the boracic acid of commerce; but this usually contains only about seventy-five per cent. of the pure acid, the other impurities being chiefly sulphates of ammonia and magnesia. The annual produce of boracic acid in Tuscany was, a few years ago, about two thousand tons, valued at more than £400,000, and it has been gradually increasing. Borax is most largely consumed in the making of glazes for pottery, but it is also used in the manufacture of some kinds of glass, in dyeing, candle-making, and chemical operations, for soldering, and as a flux in metallurgy.

Baryta and Strontia.—Both of these are alkaline earths. There are two native compounds of baryta—namely, barytes, heavy-spar, or barium sulphate; and witherite, or barium carbonate. The sulphate is used as a pigment, sometimes by itself, but more frequently mixed with white-lead. The carbonate is employed to some extent in the manufacture of pottery and glass, and in chemical works.

SULPHUR AND SULPHUR ORES.

The well-known elementary substance sulphur, or brimstone, is a yellow, brittle mineral of great commercial value. Native sulphur occurs in all volcanic regions in cavities and fissures of lava. In other places, it is commonly associated with beds of gypsum and rock-salt; and it is likewise found as a deposit about sulphurous springs, and in situations where there is decomposing iron pyrites. Almost the whole of this substance used in England (except what is obtained from pyrites) is brought from Sicily, where the gypsum and sulphur bearing formation covers a large portion of the island. The geological position of these beds is not yet accurately ascertained; for a long time they were supposed to be secondary rocks, but some recent observers think they rather belong to the Tertiary period. The sulphur is found in gypsum and limestone 'as a uniform or irregular mixture, sometimes concentrated in small parallel seams.' In clay and slate, on the other hand, the sulphur is found 'concentrated in globular masses.' There are some 50 mines in Sicily, employing about 20,000 hands. The annual produce of the island is now nearly 200,000 tons; and of all Italy, about 300,000 tons, representing a money value of £1,200,000.

Partly owing to the consumpt of sulphur in recent years for the vine disease, but no doubt more largely on account of the ever-increasing demand for it in the manufacture of sulphuric acid—the key-stone of our chemical manufactures—iron pyrites is now extensively employed as an ore of sulphur. This mineral is a bisulphide of iron, containing, when pure, 53·3 per cent. of sulphur, and 46·6 per cent. of iron. Iron pyrites is abundantly diffused. In Cornwall, where much is annually mined, it is called *mundic*, and occurs in veins; and in Northumberland and Durham, where the annual yield is also large, it is called *brasses*, and is either picked or washed out of the coal. It is also extensively mined in Yorkshire, Lancashire and Wales, and a little is found in Wicklow.

From 30,000 to 70,000 tons of sulphur ores, mainly pyrites, are raised in the United Kingdom. The annual imports, mainly from Spain and Portugal, amount to hundreds of thousands of tons, with a value of more than a million of pounds.

Native sulphur is employed to make the purer kinds of sulphuric acid. It is also used to bleach wool and silk, as a disinfectant, in the manufacture of gunpowder, in medicine, and for many other purposes. Sulphuric acid made from pyrites is never quite free from arsenic.

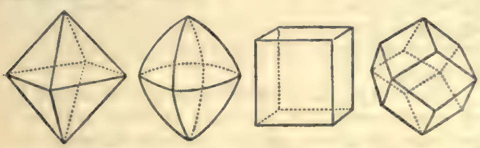
GRAPHITE OR PLUMBAGO.

Closely allied to the diamond, which comes first under our next head, is *graphite*, *plumbago*, or *black-lead*. The finer kinds of this substance consist of nothing but carbon, but more usually it contains some oxide of iron and clay. Perhaps the finest plumbago in the world for pencil-making is that obtained from the celebrated mine at Borrowdale, in Cumberland. The supply is, however, very irregular, as the mineral is found only in detached pieces in nests of trap-rock. Some years ago, a large quantity was got, and stored away by the proprietors, of which small quantities have been sold from time to time. The mine is supposed to be nearly exhausted, and has not been worked for several years. Plumbago of good quality is obtained in several parts of the world. Besides the use of the finer kinds in pencil-making, black-lead is employed in the construction of crucibles for metallurgical purposes, for giving a gloss to iron articles, and for lubricating machinery.

PRECIOUS STONES.

We have already given an account of some minerals which are semi-precious, such as jet, amber, coral, and jade. A few others of this class, as the amethyst, the turquoise, the garnet, and the onyx, will be briefly referred to in this section, which, however, will be mainly devoted to the more valuable precious stones or gems. These are the diamond, the ruby, the sapphire, the emerald, the spinel, and the noble opal. The pearl, although a gem, and largely composed of carbonate calcium, belongs properly to ZOOLOGY, as a product of the animal kingdom. All precious stones occur in small crystals, often worn into a rounded form; or in amorphous masses and concretions in some rocky matrix. When found in the sand or gravel of water-courses, they have been washed out of the parent rock. So rare and so limited in size are the finer gems, that when they approach the size of a pigeon's egg, they become of enormous, some of them of fabulous value. Most gems are composed of the same substances as many of our commonest minerals.

Diamond.—This well-known gem surpasses all others in hardness and brilliancy. No other substance will scratch the diamond, and it is not acted upon by acids and alkalies. It is, however, as first suspected by Newton, combustible, and when heated in a vessel containing oxygen, it burns with facility, yielding carbonic acid gas, thus proving that it consists of pure carbon. Its power of refracting light is very high, a property which confers upon it much of its splendour. It is believed that the true matrix of the diamond has not yet been discovered, although it is sometimes found in a loosely adhering conglomerate in Brazil, and in a friable calcareous rock at the Cape. If it be, as generally believed, of vegetable origin, it may never have had a rocky matrix like other gems. At all events, diamonds are usually washed out of loose soil of various kinds, but always, according to Dana, out of the soils of gold-bearing regions. They occur crystallised in the form of octahedrons, dodecahedrons, and other modifications of the cube, but with the sides and angles often rounded.



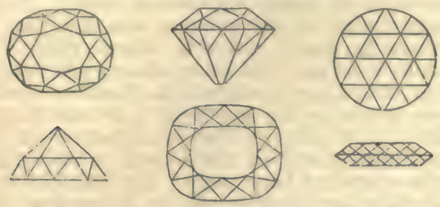
Until the early part of last century, all the diamonds of commerce came from India, where they are still found, but very sparingly. The famous mines of Golconda, which are said to have been at one time let for £150,000 per annum, with the reservation of all diamonds above ten carats in weight, and to have employed thirty thousand labourers, are now let to some natives for less than twenty shillings a year, who consider themselves lucky if they find a stone worth eight or ten shillings in a month. Borneo is perhaps the only Eastern country from which diamonds are still brought, and the number imported is comparatively small. For nearly one hundred and fifty years the world has been chiefly supplied from the Brazilian mines, the most celebrated of which are on the rivers Jequitinhonha and Pardo, north of Rio Janeiro, where the sands are washed by slaves. From first to last, about two tons of this gem have been obtained in Brazil. In the present century, diamonds have at different times been procured in the Ural Mountains; and since 1860, some have been found in New South Wales, but none of much commercial value. A new diamond-field of rich promise was, however, discovered in South Africa in March 1867. The locality is on the Vaal River, about eight hundred miles from Cape Town, and the diamond territory there is now known to stretch over one hundred miles. Kimberley is the headquarters of diamond mining, and by 1881, stones to the value of £23,000,000 had been found. The official returns give the value raised in 1883 at £2,742,470. The Porter Rhodes diamond found there weighed 150 carats uncut, and £60,000 was refused for it.

Precious diamonds are most usually transparent and colourless, but they are found of various colours, as red, yellow, green, blue, brown, and black. It is commonly stated that perfectly pure and colourless diamonds, technically said to be 'of the first water,' are of the highest value, but this is really not the case. High authorities say that those with a decided colour, such as blue, red, or green, bring by far the most exorbitant prices. Thus a diamond of a bright green colour weighing five grains has sold for £320, which, if it had been white, would not have fetched more than £28. Just before the discovery of the Cape field, a fine brilliant weighing half a carat was valued at £5, 10s.; one of one carat, at £18; one of two carats, at £65; one of three carats, at £125; one of four carats, at £220; and one of five carats, at £320. Six years after the discovery of Cape diamonds, yellows under five carats were quoted at from 40s. to 50s.; above that weight, from £3 to £4 per carat; pure white stones under five carats, £3 to £4; above five carats, £4 to £7. A carat is equal to 3½ troy grains.

The largest authentic diamond known is the 'Mogul,' found at the Gani mine, seven days distant from Golconda, and weighs 280 carats. Other famous diamonds are the Orloff or Russian diamond, weighing 193 carats; the Koh-i-noor, weighing, since it has been recut, 102½ carats; the 'Regent of France,' said to be the most perfect in existence, weighing 136¾ carats; and the Hope diamond, of a unique blue colour, weighing 44½ carats. There are still two stones much larger than any of these, but the fact of their being real diamonds is doubted.

The processes in diamond-cutting as at present practised were shewn by M. Coster of Amsterdam in the Paris Exhibition of 1867, and are as follows: The diamond is first chipped into shape by a hammer and steel knife, an operation requiring great dexterity, because it will only split in the direction of the cleavage planes; and neither too large nor too small a piece must be struck off. Two diamonds, each fastened to a stick with cement, are then rubbed together till the principal faces are, one after another, formed—two facets, that is, one on each stone, being of course made at the same time. When the chief facets are thus shaped out, the diamond, in order to have their number increased, is attached to a tool by means of a fusible metal, and held down on a rapidly revolving iron disc upon which there

are diamond-powder and oil. In this way, a great number of these facets, perfectly regular in shape, are, solely by the eye, produced, and by continuing the operation they are polished. Diamonds are cut into three forms, termed the *brilliant*, the *rose*, and the *table*, which will be understood by a glance at the following figures :



Besides its use as a gem, the diamond has been long employed by glaziers for cutting glass. Those which are black in colour or full of flaws are termed *bort* or *boart*, and are crushed to powder for the purpose of cutting the finer diamonds and other gems. Bort is, however, a costly material; but there is a peculiar, dark, opaque variety of the diamond, recently found in South America, called carbonado, which is now used for the same purposes, and is obtained at a considerably lower price. Carbonado is duller in appearance than the true diamond, but is of the same hardness. It is also employed in the dressing of millstones, and for boring hard rocks in the process of tunnelling.

Sapphire—Ruby.—Several gems which consist solely of crystallised alumina or corundum, and merely differ in colour, are in a scientific sense all the same mineral, although different names are given to them by lapidaries. If the colour of this mineral is blue, it is called a sapphire; if red, a ruby; if yellow, an oriental topaz; if purple, an oriental amethyst; and so on. The *sapphire* is next to the diamond in hardness, and next to it and the emerald in value. Both the sapphire and ruby are found chiefly in Ceylon and Pegu. A fine ruby is the most costly of all gems.

When the substance of which the sapphire and ruby are composed occurs opaque, dingy in colour, and crystalline, it is called *corundum;* and when impure and granular, it is termed *emery*. Corundum is found in India, Ava, and China, and is extensively used for cutting gems and polishing steel. Emery is still more largely employed for grinding and polishing metals, and especially plate-glass. It is used both in powder and glued to paper, and is chiefly brought from the island of Naxos in Greece.

Emerald—Topaz—Spinel Ruby—Garnet, &c.—The gems in this group are compounds of silica with various bases. The *emerald* is a silicate of aluminium and glucinum—the latter a rare earth, and the only rare substance found in any of the finer gems. Its colouring matter, hitherto supposed to be oxide of chromium, has been recently asserted to be really an organic substance analogous to the green colouring matter of leaves. The most celebrated modern locality for emeralds is the mine of Muzo in New Granada. The *beryl* is a pale-coloured emerald, called, when transparent, aquamarine. What is properly called the *topaz* is a silicate of aluminium with fluoride of silicon or aluminium. The finest kinds come from Brazil, and many of these are of a fine, deep, clear yellow colour. The *spinel* is a compound of aluminium, magnesium, and oxygen, and of the same hardness as the topaz. When of a scarlet colour, it is called *spinel ruby;* when rose-coloured, *balas ruby;* when orange-red, *rubicelle;* and when violet, *almandine ruby*. The *garnet* is a silicate of aluminium and calcium, or instead of calcium there may be magnesium, manganese, iron, or chromium. It is about the same hardness as rock-crystal, and occurs of various colours, but it is only those which are transparent, and of some shade of red, which are used in jewellery.

The *turquoise* is an opaque stone of a fine azure-blue colour, and much used in jewellery. It consists chiefly of phosphate of aluminium, has a waxy lustre, and is but moderately hard. It is found in India and Tibet.

Amethyst, Cairngorm, Carnelian, Onyx, &c.—The ornamental stones obtained from quartz and its varieties are so numerous, that we can here only notice some of the principal kinds used by the jeweller. Rock-crystal, already referred to, is the type of the crystalline and vitreous varieties. Those kinds, again, which are amorphous, translucent, and of waxy lustre, are called chalcedonic, and include carnelian, sard, agate, and onyx. A third group comprises the jaspery varieties, such as jasper and blood-stone. These substances are all composed of silica more or less pure, and usually coloured by very small quantities of other bodies. The *amethyst* is a purple or violet coloured rock-crystal. *Cairngorm stone*, whose colour ranges from a dingy brown to a pure yellow, is also a variety of rock-crystal. Both are chiefly obtained from Brazil. *Carnelian* is a variety of chalcedony, usually of a lively red, but sometimes of a yellow tint. Sard only differs from it in being of a rich brown colour, which appears blood-red by transmitted light. But it is difficult to draw a line of distinction between them. The finest carnelians are brought from Arabia, and from Cambay and Surat in India. The *onyx* and *sardonyx* are also varieties of chalcedony, in which the mineral occurs in bands of different colours. *Jasper* is a variety of quartz distinguished from those already mentioned by its being opaque. It is often richly coloured and mottled; and more rarely is beautifully striped, in which case it is called ribbon-jasper. *Blood-stone* is a dark-green kind of jasper, thickly dotted over in the finer examples with red spots, hence its name.

Opal.—The *noble* or *precious opal* is also a kind of quartz with the addition of from five to ten per cent. of water. Many persons consider a fine opal, with its wonderful play of prismatic colours, the most lovely of all gems. Opal is the softest of the stones which are composed of silica, and it is also brittle, so that it requires to be polished with great care. It is, besides, apt to lose its beauty if exposed to any considerable heat, and has the curious property of being always most brilliant on warm days. The localities for the precious opal are few, Hungary being the country where the finest are obtained. Stones as large as an inch in diameter are very rare, and if of great beauty, will fetch one thousand pounds and upwards. There is one in the Imperial Museum at Vienna whose size and splendour are unique. It weighs seventeen ounces, and is valued at from fifty to seventy thousand pounds.

METALS—METALLURGY.

OF the sixty-four elementary substances at present known, about fifty are metals, but the greater number of these are rarely seen, and still more rarely applied to any useful purpose in the metallic state; although some of those incapable of being so used form highly important compounds with non-metallic bodies, as will be found explained in our numbers on CHEMISTRY and USEFUL MINERALS. We shall devote this number almost entirely to those metals whose properties, such as strength, hardness, elasticity, malleability, ductility, fusibility, and durability, render them of great and indispensable service to man, and refer but briefly to such as are of little or no economic importance. The term metal is less easily defined now than formerly, when certain physical characters, such as lustre and high density, were alone taken into account; because we have come to know that a high metallic lustre, for example, is possessed by a few non-metallic substances, and that some metals are extremely light bodies. Still, the properties above enumerated, together with a high conducting power for heat and electricity, suffice to distinguish the metals as a class from other elementary substances.

Mercury is the only metal which is liquid at ordinary temperatures, although, with one exception, they can all be melted by the action of heat. Most of them are non-volatile, except at very high temperatures, produced by exceptional means; but a few, like zinc and cadmium, go off in vapour at a bright red-heat; while arsenic, when heated to a dull redness, passes at once from the solid to the gaseous state. Some metals and alloys, as chromium and a combination of iridium and osmium, are excessively hard, much more so than the hardest steel. Some, again, like lead and gold, are soft; but far softer, and yielding to the fingers like putty, are such metals as potassium and sodium. It is necessary, however, to keep in mind that the degree of softness in ordinary commercial qualities of a metal will vary much with even slight amounts of impurities.

METALLIC VEINS AND BEDS.

A few metals are found in the metallic state, in which case the term *native* is applied to them. Gold and platinum are always, while silver and copper are frequently so found; but others, again, like iron and lead, except in rare instances, only occur in nature in union with other substances, forming minerals called ores. The great majority of metals are obtained from their ores, which are most frequently oxides, carbonates, and sulphides; but chlorides, arsenides, phosphates, and other compounds likewise occur. As their names imply, these are chemical combinations of the metals with other elements, although most ores are also mechanically mixed with sparry or earthy impurities. Many ores, again, contain more than one metal; thus, silver and lead, iron and copper, cobalt and nickel, are very frequently found together.

Most metallic ores are found in veins, technically called *lodes;* but certain kinds of iron ore, and more rarely copper ore, are found in beds or strata. Gold nuggets are largely found in stratified drifts, which, however, have been removed from their original position in veins by denudation. Veins are rents, fissures, or hollow spaces in stratified or unstratified rocks, filled with spars such as quartz, calcite, barytes, and fluor, when non-metalliferous; and when metalliferous, with some ore along with these spars. Metalliferous veins which run nearly east and west are called *right-running veins*, and these are usually the richest, longest, and most constant in character. Other veins crossing these at right angles, or nearly so, are termed *cross veins*, these being not only shorter, but more variable in width than the former. A third intermediate class of veins, and short, irregular branches, takes all directions. In the mining districts of Great Britain, veins or lodes vary from a fraction of 1 foot to about 40 feet thick, their average thickness being 3 or 4 feet. The length of some is from 7 to 10 miles, but with such as these there is usually a doubt whether it is really the same vein throughout its length.

METALLURGY.

This word is from the Greek *metallon*, ore, metal, and *ergon*, work. A distinguished living metallurgist states that, as now understood, the term signifies the art of extracting metals from their ores, and adapting them to various purposes of manufacture. As we cannot describe a single smelting process, or system of processes, which will hold good for several metals, it will be necessary to treat the smelting of each by itself. But previous to doing this, we give a table (on next page) of nearly all the known metals, with their melting-points and specific gravities, as far as they have been ascertained. There are a few metals besides those mentioned—namely, thorinum, tantalum, cæsium, indium, and one or two more—about which very little is known.

Gold.

Since the eye of primitive man first lighted upon gold, no other metal, perhaps no other substance even, has surpassed it in interest. Its name is derived from the word *our* or *or*, which signifies in many ancient languages the light of day. Although iron is a far more indispensable material to mankind, yet there is a peculiar charm about the colour, the indestructibility, the intrinsic value, and other properties of gold, by which its place as the most highly prized of the metals will always be maintained. Even in early ages it was found in many localities, and is now known to be very widely distributed, although there are

comparatively few countries where the mining of it is found to be remunerative. In the British Islands gold was worked rather extensively in the 16th century, at Leadhills, in Scotland, and towards the end of the last century, in Wicklow, in Ireland. Of late years it has been regularly worked in North Wales, 20,000 oz. being obtained in 1862. Hungary and Transylvania, whose mines have been long famous, are the most productive of European countries, yielding annually about £300,000 worth of the precious metal, but even there it requires all the aid that the highest skill in mining can furnish, as well as very cheap labour, to yield profitable returns.

Name.	Specific gravity.	Melting-point, centigrade.	Discoverer and Date.
Platinum.....	21·50	Ox. bl. *	Wood..................1741
Osmium......	21·40	Ox. bl.	Tennant 1803
Iridium......	21·15	Ox. bl.	" 1803
Gold.........	19·50	1102°	Known to the Ancients.
Uranium.....	18·40	Agg. in forge †	Klaproth..............1789
Tungsten....	17·60	Agg. in forge	D'Elhujar 1783
Mercury.....	13·60	− 39°	Known to the Ancients.
Thallium....	11·90	294°	Crookes 1861
Palladium...	11·30	H.H. of forge ‡	Wollaston 1803
Lead.........	11·45	325°	Known to the Ancients.
Rhodium....	11·00	..	Wollaston 1803
Silver.......	10·50	1023°	Known to the Ancients.
Bismuth.....	9·90	258°	
Copper......	8·96	1091°	Known to the Ancients.
Nickel.......	8·80	H.H. of forge	Cronstedt.............1751
Cadmium....	8·70	228°	Stromeyer.............1818
Molybdenum	8·63	Agg. in forge	Hjelm 1782
Cobalt.......	8·54	H.H. of forge	Brandt................1733
Manganese..	8·00	H.H. of forge	Galm and Scheele.....1774
Iron.........	7·84	2000°	Known to the Ancients.
Tin..........	7·30	228°	" " "
Zinc.........	7·10	412°	Paracelsus (?).......1530 (?)
Chromium...	7·00	Agg. in forge	Vauquelin.............1797
Antimony...	6·80	450°	Basil Valentine....1490 (?)
Titanium....	..	Agg. in forge	Gregor 1791
Arsenic......	5·88	..	Brandt................1733
Barium......	4·00	450°	Davy..................1807
Aluminium..	2·56	..	Wöhler 1828
Strontium...	2·54	..	Davy..................1807
Glucinum....	2·10	..	Wöhler 1828
Magnesium..	1·74	433°	Bussy.................1829
Calcium.....	1·58	..	Davy..................1807
Rubidium...	1·52	38·5°	Bunsen................1860
Sodium......	0·97	97·6°	Davy..................1807
Potassium...	0·86	62·5°	" 1807
Lanthanum..	0·83	..	Mosander 1839
Lithium.....	0·59	180°	Arfwedson 1818

* Fusible only by oxyhydrogen blow-pipe.
† Agglomerate, but do not melt in forge.
‡ Highest heat of forge.

The three most productive gold regions in the world are those of the Russian empire, California, and Australia. From the sand of streams in the Ural Mountains, gold is believed to have been obtained in ancient times, and during last century much was obtained from the auriferous veins of this range. These Ural sources, though still worked, are small in their yield, compared with those of Western and Eastern Siberia, where various washings were opened up between 1829 and 1838, and for several years afterwards were the most productive in the world. The greatest supply of gold is now obtained from California, where auriferous deposits were first discovered in 1848; but the gold-fields of Australia, discovered only three years later, are nearly as productive, and the two countries together now produce about two-thirds of all the gold obtained. In the latter country, as in most gold regions, the gold-bearing veins are found in metamorphic Silurian strata; but in California they happen to occur in a much later formation—namely, the Jurassic. It is, however, not in veins of solid rock, but in alluvial deposits, where the greatest quantity of the precious metal is found. The present annual yield of gold of California and neighbouring states is variously estimated at from 8 to 10 millions sterling; that of Australia in 1871 was 7 millions; that of the Russian empire, 3½ millions; and that of the South American states, nearly 2 millions. Just before the Californian discovery, the annual produce of all countries did not exceed £7,000,000; while for the last ten years it has not, on an average, been far short of £29,000,000.

Whatever the nature of the rock inclosing auriferous veins, the productive vein itself is almost always quartz. The veins worked in California yield for every ton of material from ½ to 5 oz. of gold, but occasionally the quantity obtained is much higher. In Victoria the average yield is 1 ounce per ton, rising, however, in rare instances to nearly 300 oz. per ton. Alluvial deposits or drift contain gold which, in the long course of ages, has been slowly washed out of solid veins, and like the veins themselves, vary much in richness. In these there are what are called shallow workings or 'placers,' and deep diggings; the one belonging to recent, the other to ancient river systems. Gold is found most abundantly in the 'gutter' or bottom of the drift, which in Australia is sometimes 400 feet thick; and the auriferous portion, called the 'wash-dirt' or 'pay-dirt,' may vary from 1 foot to 12 feet thick. Where water is scarce, as in Australia, such a deposit can only be worked by skilful mining; but in California, where it is abundant, banks of this alluvial gravel are worked by what is called 'hydraulic mining;' that is, water under a pressure of from 50 to 200 feet in perpendicular height, is conveyed by flexible pipes to the face of the gravel, and by means of metal nozzles directed against the bank with great force: the gravelly mass rapidly disintegrates, and falls down in large sections. In flowing away, the water conveys the loosened gravel to a sluice, where little raised pieces in its bottom catch the gold as it falls. Banks of shingle 80 feet high can be levelled at one operation by this process, which is found to be by far the most profitable kind of placer-working where water is plentiful. The more simple and primitive methods of washing auriferous sand or gravel are by the pan and the cradle. In either case the gold is separated by agitating the mixed materials with water, so as to allow it to collect at the bottom by reason of its superior weight.

Native gold is invariably alloyed with silver; that from Australia contains only from 3 to 8 per cent.; but sometimes the silver amounts to 40 per cent. of the alloy. With all the processes in use for the extraction of gold, either an alloy of it with silver, or more rarely with copper, is first obtained. Washing is the simplest method; but when gold exists in any gangue in a state of fine division, or when, as with auriferous quartz, the whole is stamped to a fine powder, the amalgamation process is usually employed. This is conducted in several ways, but the principle in all consists in exposing the auriferous material as thoroughly as possible to the mercury. The latter dissolves the gold, and from the amalgam so formed the mercury is afterwards separated by distillation in some form of retort. Of late years, a concentrated solution of common salt saturated with chlorine gas has

been employed to extract gold, and any silver associated with it as chlorides, from which both metals are precipitated together by metallic copper or other agent. Gold is separated from the silver by several processes, but most largely by what is called the 'wet way.' By this method the alloy, previously brought to the proportion of three parts of silver to one of gold, may either be treated with boiling nitric acid (quartation), which dissolves the silver, leaving the gold unattacked; or, a similar alloy being prepared—in which, however, the exact proportion of gold matters less—it may be subjected to the action of boiling sulphuric acid, which also dissolves the silver, and so parts it from the gold.

Gold is the only yellow metal, and it is the most malleable of all. It can be beaten out into leaves not exceeding $\frac{1}{200000}$ of an inch in thickness, while still thinner is the coating of gold on silver wire used for gold-lace; and, in this case, the gold and silver are drawn out together from a rod of the one metal coated with the other. This proves that it is also very ductile, a fact otherwise shewn by the extreme fineness into which wire from gold itself can be drawn. Pure gold is nearly as soft as lead, and does not oxidise or tarnish in air or water. It is quite insoluble in any simple acid except selenic, but it dissolves in *aqua-regia*, which is a mixture of hydrochloric and nitric acids. In this case, the active agent is the liberated chlorine, the metal dissolving in solutions containing free chlorine or bromine. The specific gravity of gold is 19·5, being less than platinum and one or two other metals.

Gold intended for coinage or jewellery is always alloyed with copper or silver to harden it. Standard gold, of which British sovereigns are made, contains 22 parts of gold to 2 of copper; that is, taking the number 24 to represent pure gold, such coinage is 22 carats fine. Jewellery, watch-cases, chains, and like articles, are manufactured of alloys, which contain as a minimum one-third of their weight of gold, or 8 carats fine. The richest of these rarely exceed 18 carats fine, and by a special treatment these finer qualities take on a rich and characteristic colour. It was long believed that this colour could not be given to less than 15-carat gold, but a process has lately been discovered on the continent by which an alloy of 13-carat can be 'coloured.' Large quantities of gold are consumed in gilding, which is done in various ways, such as by the use of gold-leaf, by the electrotype process, and by painting on a mixture of its powder with varnish, which is afterwards burnished. The fine ruby and crimson colours given to glass and porcelain are produced by a compound of gold and tin.

Silver.

Silver does not stand second to gold in intrinsic value, but it ranks next to it in beauty, in the length of time it has been known, and among the precious metals in the variety and importance of its applications. It is found native rather extensively, and sometimes in crystallised or arborescent pieces of great beauty. Most native silver, however, occurs disseminated in small fragments through argentiferous ores and their associated rocks. Occasionally a very large piece is met with. One, for example, was found at Kongsberg, in Norway, weighing 560 lbs.; another at Huantaya, in Peru, weighing 800 lbs.; and a third in Mexico, weighing 2700 lbs. We have already referred to native alloys of gold and silver with an excess of gold, and may now state that such alloys are also found in which the silver greatly predominates. The ores of silver are numerous, but the great majority of them consist of compounds of sulphur and silver, some other metal being also frequently present. Silver likewise occurs in combination with chlorine, bromine, and iodine. It is scarcely ever absent from galena, the chief ore of lead, and though usually present in very small proportion, yet, from this source alone, a very large quantity of silver is now annually obtained. Of silver ores proper, the most important are *silver glance*, or *vitreous sulphide of silver*, containing, when pure, 87 per cent. of the metal; *stephanite*, or *brittle sulphide of silver*, containing, when pure, 70 per cent. of silver; *pyrargyrite*, or *ruby silver*, which, when pure, contains 59 per cent.; and *chloride of silver*, or *horn silver*, consisting of 75 per cent. of silver and 25 of chlorine.

Mexico, whose silver mines were discovered in the 16th century, has long stood at the head of silver-producing countries; but the extraordinary discoveries of ore in Nevada and adjoining states, which began so recently as 1859, will probably soon bring their produce abreast of the Mexican yield. Even now, these Pacific States of the Union are not far behind, and the annual produce of the two regions may be roundly taken as three-fourths of all the silver obtained in the world. Next in importance are the ancient mines of Peru and Bolivia, and the later, though by no means recently discovered, deposits of Chili. In Peru, the principal mines are at Cerro de Pasco, a town 13,673 feet above the sea, and containing some 18,000 inhabitants. There are two principal veins, one 9600 feet long and 400 broad, the other 6400 feet in length and 380 in breadth. The mines have been badly worked, and but for the drawbacks attending mining operations in such high and desolate regions, could probably be made to exceed those of all other districts in extent of production. In Europe, Spain is the largest producer of silver, Austria is next, and then follow Saxony, Prussia, and Great Britain. The other countries yield comparatively little, although Norway has a rich but limited mining district at Kongsberg.

Silver is extracted from its ores by several processes. One of the oldest was introduced into Mexico in the 16th century, and is still practised both there and in South America. It consists in grinding the ore to a fine powder; spreading it in heaps in the state of pasty slime on a stone floor; and adding first a small quantity of common salt, and then copper pyrites (the sulphide of iron and copper), which becomes converted into the sulphate. Mules now tread the mass for several hours, after which mercury is evenly spread over a heap, and the animals then continue to tread it repeatedly every other day till the whole is well mixed. The nature of the chemical reactions in the process is disputed; but the most recent view is that an oxychloride of copper is formed, which then combines with the sulphur of the ore, leaving the silver free to amalgamate with the mercury. The amalgam is separated from the slime by washing, and after the quicksilver is distilled off by heat, the silver is obtained in a spongy state

and nearly pure. It is then melted and cast into ingots. The European amalgamation process differs from the Mexican chiefly in the mixture of silver ore with the sulphide of iron and copper and common salt being roasted previous to the addition of mercury. It is also more carefully conducted.

Silver is most conveniently extracted from rich ores by fusing them with lead, and then extracting the silver from the alloy so obtained by cupellation. When lead is heated with free access of air, it rapidly oxidises; while silver is not oxidised at any temperature short of a very high one, even in presence of melted oxide of lead. But this oxide (litharge) in the molten state dissolves the oxides of several other metals, and consequently these can be separated along with the lead on a cupel. The cupel is a bone-ash tray filled with the melted alloy of lead and silver, and exposed to a current of air, which gradually oxidises the lead, and blows it off in the state of litharge, leaving, when the operation is conducted long enough, the silver as a cake on the cupel. Nearly all lead obtained by the ordinary smelting processes contains silver, of which 8 or 10 oz. to the ton is a very common proportion. Some kinds, however, contain only 2 or 3, while others have occasionally as much as 300 oz. per ton. By a process patented by the late Mr H. L. Pattinson of Newcastle-on-Tyne, the silver can now be profitably extracted from even the poorest qualities we have named. It is known as Pattinson's desilvering process, and is based on the fact, which he discovered, that when lead containing silver is melted, and allowed to cool slowly, a portion of the lead separates first, in the solid form, as small crystals. These contain less, and therefore the portion which remains liquid contains more silver than the original lead. Suppose, then, we began by melting a ton of lead containing 10 oz. of silver in a pot, and, allowing it to cool slowly, removed two-thirds of it in the solid state as the crystals formed. We should then have a crystallised portion containing only 5, and a liquid portion (one-third) containing 20 oz. of silver per ton. By repeating the operation with both portions, we at last get crystals containing almost no silver, and a liquid portion very rich in that metal. In practice, 10 tons of lead are melted into one pot, of which there are usually from six to nine in a row, and the concentration of the silver is not often carried further than 600 oz. to the ton. The rich lead is then submitted to the cupellation process described above. Nearly all the silver produced in Great Britain, amounting of late years to about 800,000 oz. annually, is obtained by the desilverisation of lead.

Copper.

The use of copper by ancient nations is well known, through the weapons and other objects of bronze—an alloy of copper and tin—which have been collected so largely by archæologists. It was obtained by the ancients from various places. Copper is the only metal with a red colour, and is very malleable and ductile, but in tenacity it is far inferior to iron. Its melting-point is between those of gold and silver, and when heated closely up to it, it becomes very brittle, a property taken advantage of by founders when they wish to break up ingots of the metal.

Native copper, although frequently met with wherever copper ore occurs, both as a constituent of the ore itself, and also in separate arborescent pieces, laminæ, and irregular lumps or blocks, is yet rarely found in sufficient quantity to be systematically worked. The chief locality for it is Lake Superior, where in some years as many as 6000 tons have been obtained. Dr Percy, in his large work on Metallurgy, states, on the authority of a well-known mining engineer, 'that at Minnesota, in 1854, not fewer than forty men were engaged during twelve months in cutting up a single mass of native copper, weighing about 500 tons!' Copper ores are found in a great many countries, but it is only in some that they are smelted. Large quantities of ore from Australia and South America, for example, are smelted in England. The richest ore of copper is the red oxide, which contains, when pure, nearly 90 per cent. of the metal. Green carbonate of copper is a widely distributed ore, occurring largely in Australia and Russia. In a pure state it contains 57 per cent. of copper, while the blue carbonate frequently associated with it contains only 55 per cent. These carbonates yield a high quality of copper. Some of the sulphides are also valuable copper ores; two of them, namely, gray sulphide and purple copper, contain respectively, when pure, 80 and 55½ per cent. of metallic copper. Copper pyrites—a sulphide of iron and copper—which is the most abundant ore of the metal, and the one chiefly found in Cornwall, contains in the pure state 35 per cent. of copper, although, on account of impurities, the average yield of what is obtained in England is not more than 12 per cent.

In practice, the process of smelting copper from ores like the Cornish is somewhat complicated, but in theory it is comparatively simple. The main impurities of the ore are quartz, iron, sulphur, and very commonly arsenic. The process is conducted with the view of separating the iron and quartz as a fusible slag, and of dissipating the sulphur and arsenic, by converting them into sulphurous and arsenious acids, through oxidation in the furnace. At Swansea, which is the seat of copper-smelting in this country, reverberatory furnaces are used, and these are of two kinds, called respectively calciners and melting furnaces. A section of a melting furnace is given in fig. 1. There are never fewer than *six operations* in the Welsh process, and when so limited,

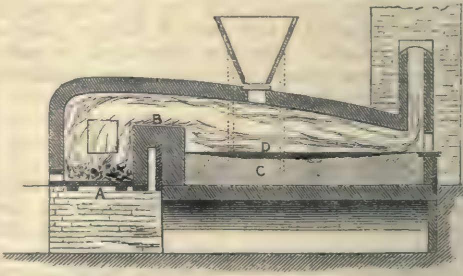


Fig. 1.—Section of Copper-melting Furnace:
A, fireplace; B, fire-bridge; C, bed of sand; D, melted copper.

a favourable admixture of ores is necessary. In the *first*, the ore is calcined in a furnace for at least twelve hours, by which time the greater part

of the sulphide of iron is decomposed, and much sulphurous and other acids have formed and escaped in fumes. In the *second*, the calcined ore is melted along with siliceous slags obtained in later stages of the process. Here a fusible slag, consisting in great part of silicate of iron, is formed, and the sulphides of iron and copper are run off as a regulus, termed *coarse metal*, and granulated in water. In the *third*, the coarse metal is calcined again for twenty-four hours, during which time most of the sulphide of iron is converted into oxide. In the *fourth*, the calcined coarse metal is melted with slags rich in oxide of copper, and also with rich ores, as oxide and carbonate. These oxidise any sulphide of iron remaining, and a regulus called *white metal* is formed, consisting almost entirely of disulphide of copper, and containing about 75 per cent. of the metal. In the *fifth*, called 'roasting,' the regulus is very slowly melted, so as to allow of the gradual and thorough reduction of the disulphide by heated atmospheric air through the formation of oxide of copper. When oxide and disulphide of copper are heated together, they decompose each other, the sulphur escapes as sulphurous acid, and impure metallic copper, called *blister copper*, is produced. In the *sixth*, the copper from the previous operation is refined. To effect this, it is melted in a furnace, and exposed to the oxidising influence of the air for from fifteen to twenty hours, by which time it is full of dioxide, and this is in turn reduced by throwing pure coal on the surface of the molten metal, and then stirring it with a pole of green birch-wood. For the last ten years the produce of copper ore from British mines has been steadily decreasing. In 1871, the total ore raised amounted to 97,129 tons, yielding 6280 tons of copper, the value of which was £475,143; but for the year 1880, the figures were little more than half. Large quantities of foreign and colonial ores are now, however, smelted at Swansea; and further, there has been, during the past decade, a gradually increasing yield of copper from the pyrites employed to make sulphuric acid in chemical works. The total quantity of copper ore smelted in England and Wales in 1871 was 399,624 tons, yielding 29,953 tons of copper.

Copper is used for a great variety of purposes. Wanting in the strength of iron, it has yet the advantage over that metal of not being acted on by moist air or pure water, but solutions of the chlorides—sea-water, for example—gradually corrode it. Nevertheless, it has been very largely employed as a protective sheathing for the bottoms of wooden ships. Boilers, stills, cooking-vessels, pipes, wire and wire-cloth, nails, spikes, and many other articles, are made of copper, and used in circumstances where iron, through its tendency to rust, would scale away, or stain objects brought into contact with it. A very large quantity of copper is used for engraving pictures and designs upon. Copper is admirably adapted for producing works of art in electro-deposit instead of casting them. This process is now extensively employed, and does even for objects as large as life-size statues. In this way, too, iron castings can be coated thinly over with copper, and this, when darkened, forms the most durable imitation of bronze. Some compounds of copper produce green and blue pigments, and others are used for imparting green and red colours to glass and pottery.

Not less important than the applications of copper itself are those of its alloys. *Brass*, which consists of copper and zinc in varying proportions, but very generally of two parts of copper to one of zinc, is widely employed. Articles of all kinds are made of it on an enormous scale in Birmingham. Brass is not only cheaper than copper, but it is harder, and resists atmospheric influences better. It is also more easily fused, and, with carefully prepared moulds, produces very sharp castings; it is highly malleable and ductile, so that it can be hammered, stamped, or drawn into wire with facility; and it has an agreeable colour, which, however, soon blackens if not protected by a coating of lacquer. Dutch-metal, ormolu, pinchbeck, Mannheim gold, and prince's metal, are all varieties of brass. Bronze, gun-metal, bell-metal, and speculum metal are alloys of copper and tin.

Iron.

From a comparatively early period, this happily abundant substance has been recognised as by far the most important and indispensable of all metals. Yet there was a time when bronze did service in its stead, and gold, silver, and copper are of older renown. But even since Dr Ure, writing in 1839, said that 'iron accommodates itself to all our wants, our desires, and even caprices,' what extraordinary changes have been worked through new applications of iron! Railways, and engineering works connected with them, merchant and navy ships, artillery and war *matériel*, are now, through the aid of the steam-hammer and numerous improvements in the manufacture of the metal, constructed on a scale and in a manner not even dreamed of thirty years ago.

Chemically pure iron can only be prepared, and that with difficulty, by careful processes on a small scale in the laboratory. A very high authority on metallurgical subjects, Dr Percy, states that the only pure iron which he has seen is that deposited from solution by electrolysis. It has a grayish-white colour, is susceptible of a high polish, and has a specific gravity of 8·139. It differs from the purest commercial iron in not having its malleability affected by rapid cooling after being raised to a high temperature, and also in conducting electricity better. Samples of perfectly pure iron, however made, ought not, of course, to differ in quality or in properties; and the fact that there are so many commercial qualities of malleable iron varying but slightly after all in the proportion of impurities they contain, and yet differing greatly in value, proves that our manufacturing processes are far from being perfect. All high-class iron is either obtained from the purest ores and fuel, or the manipulations through which it passes are very tedious and laborious.

Except in one or two instances, which are scarcely free from doubt, native iron of terrestrial origin has not yet been found. Meteoric iron may therefore be regarded as the only form of the native metal, and is usually rather an alloy of iron and nickel than pure iron. A few of these meteorites have been discovered, weighing from 1000 to fully 30,000 lbs.

Iron ores are abundantly distributed over the surface of the globe, and occur in every geological

formation. But such as are rich in the metal, or from which it can be extracted with comparative ease and profit, are only plentiful in certain districts; and in some countries where they do occur, the localities are so inconveniently situated for cheap carriage, that ores, even of the richest kind, cannot be profitably mined. The leading kinds of iron ore are: 1. Magnetic or black oxide of iron; 2. Hæmatite, or red oxide of iron; 3. Brown hæmatite, or hydrated sesquioxide of iron; 4. Spathic carbonate of iron; 5. Clay, or earthy carbonate of iron, including the black-band variety.

1. *Magnetic oxide of iron* is the richest ore, containing, when pure, nearly 73 per cent. of iron. It was formerly called loadstone, and has been long worked in Norway, Sweden, Russia, India, Canada, and the United States, where, as in other countries, it is found in igneous and metamorphic rocks. It is usually smelted with charcoal, and the ore having few impurities, a high-class iron is thus produced.—2. *Hæmatite, or sesquioxide of iron,* is nearly as rich in iron as the last, containing, when pure, 70 per cent. Chemically, it is the same thing as iron-rust. When crystallised, it is called specular iron ore. It often occurs in compact reniform pieces, called 'kidney ore.' A good deal of hæmatite is, however, found as a loose, soft, earthy powder. This fine ore occurs largely in England at Whitehaven and Ulverstone, where it fills up hollows in the mountain-limestone. More usually, it takes the form of a regular dike or vein. Fully 2,200,000 tons of it were raised in England in 1871.—3. *Brown hæmatite, or hydrated sesquioxide of iron,* contains, when pure, 60 per cent. of iron. It is not so rich, therefore, as red hæmatite, and also differs from it in containing about 14 per cent. of water. Brown is easily distinguished from red hæmatite by its brown streak, that of the latter being red. Under the name brown hæmatite are included not only the compact kinds, often botryoidal, mammillated, and fibrous, but also bog-iron ore and other earthy varieties. In England, this ore is found most largely in the Forest of Dean, and in the Oolite of Northamptonshire, where it occurs in an earthy form, and in superficial deposits. In 1871, 2,000,000 tons were raised. Earthy brown hæmatite is the chief ore worked in France and Belgium.—4. *Sparry carbonate of iron, spathose or spathic iron ore.* This ore is, as its name denotes, a sparry marble-like substance. When pure, it contains 48 per cent. but it is usually mixed to a considerable extent with manganese, and also with a little magnesia. It occurs abundantly in Prussia, and the iron made there from spathic ore is highly prized for making steel. In England, spathose ore is worked in the Brendon Hills and at Exmoor, and has also been noticed at one or two places in Scotland.—5. *Clay and black-band ironstones, earthy carbonates of iron.* These are the ores from which most of the iron made in Great Britain is smelted. They are found as balls or nodules in the shales, or form continuous beds of themselves in the strata of the coal-measures. Ore of this kind also occurs over an extensive area of the Lias formation in Yorkshire, as well as to some extent in the Wealden and Tertiary of the south of England. Being dull, earthy, slaty, or stone-like substances, their value has, in some instances, only been discovered in recent years, and occasionally after large quantities of valuable material had been rejected as worthless.

The following analysis will give a good idea of the composition of three leading varieties of British argillaceous iron ores. No. 1, by J. Spiller, is from the coal-measures, Lowmoor, Yorkshire; No. 3, by Dr Murray Thomson, is Scotch black-band from the same formation; and No. 2, by A. Dick, is from the Lias (Cleveland) district of Yorkshire:

	No. 1.	No. 2.	No. 3.
Protoxide of iron	36·14	39·92	36·47
Sesquioxide of iron	0·61	3·60	..
Protoxide of manganese	1·38	0·95	4·16
Alumina	0·52	7·86	3·69
Lime	2·70	7·44	2·75
Magnesia	2·05	3·82	·77
Potash	..	0·27	..
Silica	..	7·12	9·26
Carbonic acid	26·57	22·85	23·26
Phosphoric acid	0·34	1·86	trace
Bisulphide of iron	0·10	0·11	·30
Water { hygroscopic	0·61	..	·93
Water { combined	1·16	2·97	
Organic matter	2·40	trace	17·92
Insoluble residue, chiefly silica and alumina	25·27	1·64	..
	99·85	100·41	99·51
Metallic iron per cent	29·12	33·62	28·36

It will be seen that these are far from being pure ores. Manganese, calcium, and magnesium carbonates, clay, phosphoric acid, sulphur, and potash, are the foreign substances most frequently present in them, and of these, sulphur and phosphorus are the most deleterious. All argillaceous ores undergo a preliminary roasting before being smelted. Clay iron-stones lose from 25 to 30 per cent. and black-band ores from 40 to 50 per cent. of their weight by calcination. The loss is chiefly carbonic acid and water, and there is left oxide of iron, and earthy or clayey matter.

Except in savage or semi-civilised countries, where more primitive methods are in use, iron ore is now always smelted in a blast-furnace. This is a circular tower of massive brickwork hooped round with strong iron rings, or it is wholly cased with malleable iron plates, in which case the brickwork is not so thick. Until lately, blast-furnaces were seldom built more than 60 feet high; but many recently built ones are as high as 80 and even 100 feet, as it is found that a saving of fuel is obtained by the additional height. Internally they vary much in form, but perhaps the barrel shape is the most prevalent. They are, of course, lined with fire-brick: Fig. 2 is a diagrammatic section shewing a blast-furnace and blowing-engine. There is an arrangement for heating a coil of pipes in connection with the blowing-engine, by which a powerful 'blast' of air heated to from 600° to 1000° F. is made to enter the lower part of the furnace at several points by nozzles called tuyères. This is what is called the 'hot-blast;' but the old 'cold-blast' is still used to a small extent, and is considered to produce a superior iron. The materials put into the blast-furnace, technically termed the 'charge,' are calcined ore, coal or coke, and limestone to act as a flux. Taking the simplest view of matters, what takes place during the operation of smelting is this: The metallic iron is reduced from the

oxide partly by the incandescent carbon of the fuel, but more largely by carbonic oxide gas, which is formed in large quantity in the furnace. But as both the ore and the fuel contain such ingredients as clay and sand, these must be converted into a fusible slag with lime, in order to separate them from the metal, otherwise the siliceous matter would form a slag of silicate of iron, or, in other words, the slag would in that case abstract the iron to the loss of the smelter. The action of the furnace is continuous—that is, ore, fuel, and flux are regularly thrown in at the top, and towards the bottom of the furnace melted iron is always trickling down and accumulating on the hearth. The slag, which floats on the top of the liquid metal, flows out over what is called the dam, and

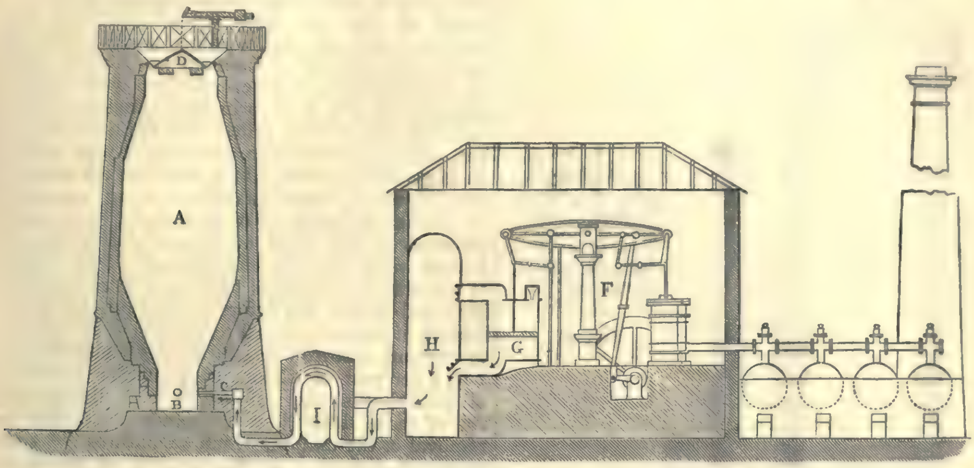


Fig. 2.—Hot-blast Furnace.

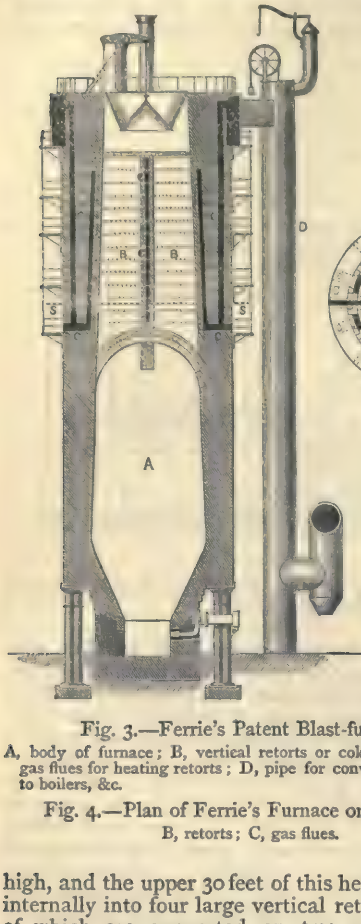
A, body of furnace; B, hearth; C, tuyère, by which hot air enters; D, belt and cone for closing mouth of furnace; F, blowing-engine; G, blowing-cylinder; H, receiver; I, oven for heating blast-pipes.

by means of a tapping-hole, the molten cast-iron is run off twice or thrice in twenty-four hours. It is run out into parallel rows of open moulds formed in the sand; the pieces so made are termed pigs, hence the name pig-iron.

We shall now take a glance at the successive improvements which have been introduced in the manufacture of cast-iron; and as these relate mainly to reducing the cost of production by economising fuel, they are especially interesting at the present time. Previous to 1618, when Lord Dudley introduced coal, the only fuel used for smelting was charcoal; but the iron-masters of that day did not like the change, and so charcoal continued to be used till Abraham Darby tried coal again at Coalbrook-dale in 1713. The make of English iron, however, fell off greatly with the innovation, and did not rally till the introduction of coke about 1750. This at once gave a great impetus to the manufacture; and not long after, namely, in 1770, came Watt's steam-engine, which changed the scale on which not only this, but every other manufacture, could be carried on. The next great improvement was the introduction of the hot-blast by Neilson of Glasgow in 1830, which, roundly speaking, saved about one-half of the fuel previously required to produce a given amount of iron. Since then, several plans have been tried for still further saving fuel, chiefly by collecting and burning the gases generated in the furnace to produce heat; it being well known that, in the case of open-mouthed furnaces, at least two-thirds of the heating power of the coal is wasted through the escape of combustible gases into the air. It is not a little remarkable that a plan for the utilisation of these gases was patented in France by Aubutot as far back as 1811, and that, moreover, this iron-master appears to have clearly foreseen its value. In England and Scotland it is scarcely more than twenty years since the saving of the 'waste gases,' as they are termed, was seriously attempted. For reasons which we have not room to state here, nearly all the early attempts to utilise advantageously the gases in question decidedly failed. Yet the prize awaiting even moderate success was great, and the waste of fuel going on almost culpable. Take the Cleveland district of Yorkshire, for example, where not a single furnace existed till the middle of this century, but which now sends annually 1,000,000 tons of iron into the market. There the waste gases are successfully collected and consumed, saving, according to one of the leading iron-masters in the district, 600,000 tons of coal per annum. In that part of the country, too, nothing but coke is used for smelting, so that in Scotland, and in those parts of England where bituminous coal is used, the coal-gas generated in the furnace is also to be considered.

In those iron-works where the waste gases are consumed for heating purposes, the most common method of preventing their escape is this: The mouth of the furnace is closed by what is called a cup and cone valve, which only requires to be opened at intervals to admit of the furnace being fed. When shut, the gaseous products, of which the carbonic oxide is the most useful portion, are forced along a large pipe or pipes to the steam-boilers and heaters, where, by a suitable arrangement, they are burned in lieu of coal. Formidable difficulties, however, attend this plan when raw coal is used, and this has led Mr Ferrie,

of the Monkland Iron-works in Lanarkshire, to try another and very ingenious method, which an experience of more than two years has proved to be singularly successful. It is shewn in figs. 3 and 4. The furnace requires to be about 80 feet



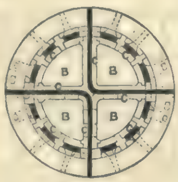


Fig. 4.

Fig. 3.—Ferrie's Patent Blast-furnace:
A, body of furnace; B, vertical retorts or coking chambers; C, gas flues for heating retorts; D, pipe for conveying waste gases to boilers, &c.

Fig. 4.—Plan of Ferrie's Furnace on Line SS:
B, retorts; C, gas flues.

high, and the upper 30 feet of this height is divided internally into four large vertical retorts, the walls of which are supported on two narrow arched rings, like flying buttresses, at right angles to each other. Round this four-chambered portion of the furnace, and through the cross divisional walls separating the chambers or retorts, flues travel in a kind of spiral direction. In these flues the gas from the furnace is burned with a proper supply of air, and keeps them at a bright red-heat. The lower portion of the furnace is constructed in the ordinary way. The object of the arrangement is to convert the raw coal into coke in the retorts before it descends into the lower zones of the furnace, and so economise the heat which in ordinary furnaces is spent in distilling the volatile products from the coal. The reduction of the iron is thus effected with much the same ease as when coke is used to begin with, while the gases generated by coking the coal in the upper or retort portion of the furnace, are employed in heating these retorts. In other words, the gaseous products from the fuel of an earlier, are used to distil off these same products from the coal of a later, charge. But the available gas is not nearly all consumed in doing this; a large quantity being used in raising steam, heating the blast-pipes, and for other purposes. By this self-coking furnace of Mr Ferrie's, only 34 cwt. of coal are required to produce a ton of pig-iron, while 53 cwt. are necessary with open-topped furnaces.

Cast-iron contains from 3 to 5 per cent. of carbon; steel contains a less quantity of this element; while malleable iron is practically free of it. Carbon has an extraordinary influence in changing or modifying the properties of iron; so much so, that any specimen of the metal containing, say, 3 per cent. another containing 1 per cent. and another containing no carbon, differ as much from each other as three quite distinct metals. Of the three principal varieties of iron, cast-iron is the most brittle and the most fusible; but, unlike steel or wrought-iron, it can neither be forged nor welded. It is used for all kinds of iron castings, large quantities being consumed for the heavier portions of machinery, for building purposes in the form of pillars and beams, for hollow ware, and for ornamental work. Much of the cast-iron made is converted into malleable iron and steel; but before taking up the manufacture of these, it is well to state that, in addition to carbon, cast-iron nearly always contains from 1 to 2 per cent of silicon, with smaller quantities of phosphorus and sulphur. It is the getting rid of these deleterious substances, and not the removal of the carbon, which constitutes the great practical difficulty in the making of the more useful kinds of wrought-iron and steel.

The ancient method of converting cast into malleable iron by a charcoal finery or hearth, is still practised in this and other countries; but the conversion is now much more largely accomplished by the process of puddling.

When pig-iron is to be converted into malleable iron by the puddling process, as a preliminary step it is sometimes, but not always, *refined.* That is, it is melted on a hearth called a refinery, covered with coke, and exposed to a powerful blast of cold air. The operation lasts about two hours, during which time the iron loses a considerable proportion of carbon, and is termed 'refined iron' or 'refined metal,' neither of which is a very appropriate term for a half-finished product. As a rule, only the best qualities of iron now pass through the refining stage, but sometimes there is a convenience in partially charging the puddling furnace with 'refined iron' for the commoner kinds. *Puddling* was invented by Henry Cort in 1784, and time has proved it to be one of the greatest improvements ever introduced into the manufacture of wrought-iron. The ordinary puddling furnace is represented in fig. 5. It is reverberatory, and has a hearth, B; a fire, A; a fire-bridge, D; and a chimney at C. A charge usually amounts to about 5 cwt. of which from one-fifth to one-half is refined iron, and the rest consists mainly of pig-iron with a variable proportion of hammer-slag and iron scale. In about half an hour, when the furnace is in working order, the charge is melted, and is then stirred or 'rabbled' for a considerable time, when it begins to 'boil' by the formation and escape of carbonic oxide, which forms jets of blue flame all over the surface. Gradually, as the carbon of the pig-iron is more and more oxidised, pasty masses of malleable iron separate, and these are removed in balls commonly weighing about 80 lbs. but

sometimes larger. About an hour and a half is required to work off a charge.

The puddled ball so formed is a spongy lump

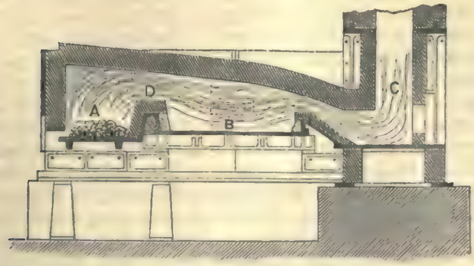


Fig. 5.—Puddling Furnace:
A, fireplace; B, hearth on which the iron is puddled; C, chimney; D, fire-bridge.

of malleable iron, mixed with liquid cinder, and requires to be welded into a coherent mass, an operation which at the same time squeezes out the cinder. This is called *shingling*, and is usually done either by a tilt or lever hammer, or by a direct-acting steam-hammer. After being thoroughly hammered into a solid oblong mass, the iron is formed into bars by means of grooved rollers at the rolling-mill. This product is called puddled bar, and in order to produce finished iron, these bars are next cut into short lengths, and formed into a pile of convenient size, which is then raised to the welding heat, hammered and rolled into any required form of bar, sheet, or plate. Sometimes this 'piling' operation is done twice.

Malleable iron differs greatly in its properties from cast-iron. The latter is practically incompressible, but it can be comparatively easily torn asunder. Malleable iron, on the contrary, possesses great tenacity, and is, moreover, very malleable and ductile, so that, when heated, it can be rolled into sheets as thin as paper, or drawn into the finest wire. Unlike cast-iron, it is very difficult to fuse, but it possesses the valuable property of welding—that is, two pieces can be completely united together by hammering at a white-heat. Malleable iron is employed for an endless variety of articles requiring strength and lightness combined. Most of the lighter portions of machinery are constructed of it. Much is consumed in the manufacture of locks, hinges, nails, wire-work, and small sheet-iron vessels, included under the general term 'hardware.' In constructive architecture and engineering, its use is greatly extending for roofs, floors, bridges, and the like; while for shipbuilding it is now almost the only material employed, so far as the frame-work and sides of vessels are concerned. Armour-plates and guns for heavy shot have of late years been made of wrought-iron, of extraordinary size, and especially thickness, for a material so difficult to manipulate in large masses.

Steel differs from malleable iron in containing a varying proportion of carbon, usually from ¼ to 2 per cent. When rich in carbon it closely resembles cast-iron in composition, except that it is more free from impurities. Steel can be made by adding carbon during the direct reduction of a pure iron ore in a furnace or crucible, but the results of this method are scarcely ever uniform. The finer kinds of steel are still made by the old cementation process—that is, by the roundabout plan of first converting cast into malleable iron, by depriving the former of its carbon, and then adding carbon again by heating the iron with charcoal. The bars of malleable iron are put lengthwise in layers into fire-clay chests or troughs, with ground charcoal between each layer. A suitable fireplace heats the troughs, which are in pairs, and the whole is kept at a glowing red-heat from seven to fourteen days, according to the kind of steel required. When sufficiently cool the bars are removed, and are found to have undergone a remarkable change. They have lost their toughness, and are now quite brittle and fusible, besides being covered all over with blisters; hence the name 'blister-steel.' These are supposed to be formed by the evolution of carbonic oxide gas. Blister-steel is not homogeneous, and requires to be melted in crucibles and cast into ingots before it is fit to be made into cutting instruments and other objects where soundness and uniformity of texture are required. Hammered or tilted steel has a remarkably fine grain, and is of great tenacity if the operation be carefully performed. Shear-steel is made by welding together a number of pieces of blister-steel under the hammer, so as to form a single bar with a section of about two inches square. If this is broken in two, welded together, and drawn out again, it forms double shear-steel.

The boldest and most noted attempt which has yet been made to improve on the older methods of making both malleable iron and steel, is that of Mr Henry Bessemer, whose process was patented in 1856. Bessemer's first idea was to blow air through molten cast-iron till either malleable iron or steel was produced; but his process is only suitable for making steel, for which it required to be modified.

The various steps in the Bessemer process, as at present conducted, are as follow: Pig-iron is melted either in a cupola or reverberatory furnace, and run in the liquid state into a converting vessel, such as is shewn in section in fig. 6. This converter, or 'kettle,' as it is called in Sheffield, is of wrought-iron, lined either with fire-brick or with a siliceous material called 'ganister,' and is suspended on trunnions, so as to admit of its being turned from an upright to a horizontal position by means of hydraulic apparatus. The capacity of a converter varies from three to seven tons. In the bottom there are seven tuyères, each with seven holes of one half-inch in diameter, through which atmospheric air is blown with a pressure of from 15 to 20 lbs. per square inch by a blowing-engine. The molten iron in the converter is therefore resting, from the first, on a bed of air, the strength of the blast being sufficient to keep it from falling through the tuyères into the blast-way. During the blowing off of the carbon at this stage a striking and magnificent effect is produced by the roar of the blast, and the volcano-like shower of sparks and red-hot fragments from the mouth of the converter, as well as by the dazzling splendour of the flame. In about fifteen or twenty minutes, the whole of the carbon is dissipated, the temperature of the metal having meanwhile risen higher than that produced by any other metallurgical operation. This first 'blow being over, the converter is lowered to a horizontal position,

and presently a red stream of molten spiegeleisen is run into its mouth, till it amounts to from 5 to 10 per cent of the whole charge. The spiegeleisen restores the proper amount of carbon to produce steel; and after it is added, the blast is

Fig. 6.—Bessemer Converting Vessel:
a, a, a, tuyères; *b*, air-space; *c*, melted metal.

again turned on for a few minutes to secure its thorough incorporation. A man standing on a small platform can by means of the hydraulic machinery empty the contents of the huge converters into the ladle, raise or lower the ladle itself, and turn it round from point to point, so as to fill the moulds by means of a plug in its bottom. Steel made in this way is not sufficiently dense, and accordingly the moulds are lifted off the ingots by means of a hydraulic crane, and the latter removed while still hot, and condensed under heavy steam-hammers. After this, they are rolled into rails, tires, plates, and various other heavy objects, for which this steel has been found to be suitable.

Until very lately, Bessemer steel has only been made from a high-priced pig-iron such as that obtained from hæmatite; but in the year 1879, Messrs Thomas & Gilchrist, by adopting a basic instead of an acid (siliceous) lining to the Bessemer converter, succeeded in making good steel from Cleveland and other cheap pig-irons. Previously the difficulty had been to get rid of the phosphorus so commonly present to an injurious extent in these, since it destroyed the usual siliceous lining. When, however, a lining of magnesian limestone made into bricks, and fired at a high temperature, is used, it provides, with the help of some lime and oxide of iron, a base for the phosphoric acid to combine with, and thus this deleterious body is eliminated from the steel. Indeed it seems to be the case that sulphur, another common impurity, is removed during the process as well. This method of converting impure pig-iron into steel has already become a most important one.

Since the year 1868 what are called the Siemens and the Siemens-Martin processes of making steel have become rapidly developed. In both the hearth portion of the furnace used resembles that shewn in fig. 5, but Siemens' gas-producers and regenerators are employed. Dr Siemens' direct process consists in melting 5 tons of pig-iron on the bed of the furnace, adding to this 2 to 2½ tons of any rich and pure iron ore, and finally some spiegeleisen—a small quantity of limestone being from time to time thrown in during the operation. In the Siemens-Martin process, pig-iron is also first melted down, but either iron or steel scrap is then added to the extent of from 3 to 10 times the weight of pig; and finally, as in the direct process, a certain quantity of spiegeleisen or ferro-manganese, each of which contains a known percentage of carbon and manganese, is thrown into the molten metal, which is then cast into ingots. It is well to bear in mind that the steel so produced cannot be tempered like crucible steel.

Like wrought-iron, steel is malleable, ductile, forgeable, and weldable; but it differs from wrought-iron in being fusible and highly elastic, as well as more tenacious. It also takes a higher polish, and rusts less easily; but the most characteristic and useful property of steel is that by which it can be tempered to any degree of hardness. Thus it is made exceedingly hard and brittle if plunged while red-hot into cold water, but its original softness may be restored by reheating and then slowly cooling it. When it is first hardened in the manner just stated, the various degrees of hardness are given by reheating and suddenly cooling it at different temperatures. The 'temper' or hardness is shewn by the colour the steel assumes during the process of reheating, as the following table, taken from Parkes' *Chemical Essays*, will explain:

Temperature.		Colour.	Temper of various articles.
Cent.	Fahr.		
221°	430°	Very pale yellowish.	Lancets.
232°	450°	Pale straw.	Best razors, and most surgical instruments.
243°	470°	Full yellow.	Common razors, penknives, &c.
254°	490°	Brown.	Small shears, scissors, cold chisels for cutting iron *cold*, hoes.
265°	510°	Brown, dappled with purple spots.	Axes, plane-irons, pocket-knives.
277°	530°	Purple.	Table-knives, large shears.
288°	550°	Bright blue.	Swords, watch-springs, bell-springs.
293°	560°	Full blue.	Fine saws, daggers, augers.
316°	600°	Dark blue.	Hand and pit saws.

Until within the last fifteen years, steel received its chief application in the manufacture of cutting-tools and instruments used in different trades, small-arms, domestic cutlery, wire of various kinds, springs, needles, steel pens, and other objects of limited size. For these purposes a fine quality of steel is required; but, at the present time, the cheaper kinds made by the Bessemer and Siemens-Martin processes are replacing malleable iron with great advantage for many objects of large size. Among these are rails and plates, ships, toothed wheels, shafts, cranks, bells, and heavy guns. Steel rails are now very largely used; and owing to the new processes, steel rails lately costing £45 a ton, could, in 1885, be bought for £5. In the construction of large tools, steel is

frequently welded to iron, so that only the actual cutting portion is formed of the former. There is, however, a difficulty in welding steel to wrought-iron owing to the difference in their melting-points, which produces an inequality in their plasticity at the welding heat, and therefore the hammer has a greater effect on the one than on the other. From its superior strength and hardness, there is little doubt that steel will yet be much more largely substituted for wrought-iron as the processes for manufacturing it on the large scale become simplified and improved. Looking back for but a single decade, the progress made in this direction is perfectly wonderful, and cannot be matched by the achievements of any former period.

In 1740, the entire quantity of iron made in Great Britain is believed not to have exceeded 25,000 tons; in 1802, the annual make was estimated at 170,000; in 1828, at 702,584; and in 1839, at 1,512,000 tons. In 1854, the first year of the carefully collected statistics now published annually by the Mining Record Office, the produce was 3,069,838, and from that time to the present it has gradually risen to nearly 8,000,000 tons. A very large amount of this pig-iron is converted into malleable iron, as there are now nearly 7000 puddling furnaces in the country. Of sheet-iron for tin plates, which are principally manufactured in Wales, no less a quantity than 130,000 tons is now annually made. On the continent, the iron manufacture is rapidly extending in France, Prussia, Austria, Belgium, Sweden, and Russia. In Sweden especially, much steel is now made by the Bessemer process; and in Prussia, where spiegeleisen is produced, one single maker—namely, Krupp, of Essen, made in the year 1882 as many as 300,000 tons of cast-steel, converted in the first instance by the puddling process. The great iron-smelting districts of England are situated in Yorkshire, especially North Riding, Staffordshire, Durham, Cumberland, Lancashire, and Derbyshire; Glamorganshire and Monmouthshire, in Wales; and Lanarkshire and Ayrshire, in Scotland. There are no iron-smelting works in Ireland. South Staffordshire is the chief seat of the malleable-iron manufacture, and Sheffield of steel; although there are signs that before long Bessemer steel will be most largely made in the hæmatite districts of Lancashire and Cumberland.

Lead.

The use of this metal is said to be mentioned in the earliest writings, and indeed the bright metallic look of ordinary lead ore (galena) could scarcely fail to attract the attention of the first workers in metal, although native lead itself is of very rare occurrence. Various minerals containing the metal in the state of carbonate, sulphate, phosphate, or arsenate, are occasionally smelted as ores of lead. The quantity of metallic lead obtained from these is, however, quite insignificant, compared with what is derived from galena or sulphide of lead. This ore is pretty generally distributed, but by far the largest supply is obtained in Great Britain and Spain. In the British Islands, it is found in the Silurian and Devonian rocks; most largely, however, in those of the carboniferous limestone formation. About one-third of the whole British produce is obtained from a cluster of mining districts situated near the centre of that narrow portion of our island which is formed by the four most northern English counties. Cornwall, Derbyshire, Shropshire, and Yorkshire also yield large supplies. Wales is peculiarly rich in lead ore; so likewise is the Isle of Man; and the galena found there and in Cornwall contains a very high percentage of silver. Neither Scotland nor Ireland produces much lead.

When pure, galena consists of 86·57 of lead and 13·43 of sulphur. Several kinds of furnaces are used in lead-smelting. The Flintshire one is reverberatory, and somewhat resembles that shewn in fig. 1. The charge, which consists of about 20 cwt. of galena, is first calcined at a comparatively low temperature for about two hours. This converts by oxidation much of the sulphide into the sulphate of lead. These react upon each other on the temperature being raised in the next stage, when a large quantity of lead is reduced, and sulphurous acid formed. In the last stage, lime is thrown in to form a stiff mixture with the slag and any unreduced ore, which is then drawn up the sloping sides of the furnace, and remelted. In five or six hours, the charge is worked off, the lead being run into a large pot, and afterwards into ingot-moulds to form pigs.

Freshly cut lead has a bright metallic lustre, but, except in perfectly dry air, it soon tarnishes, and turns gray by taking on a superficial coating of oxide. When exposed to the atmosphere for a few years, the surface becomes coated with carbonate of lead. On account of its softness, lead will make a gray streak on paper, and for the same reason, two freshly cut pieces will adhere firmly, if pressed together with some force, somewhat in the same way as two pieces of iron, when previously softened by heat, adhere after they are hammered. Lead has an extremely dull sound when struck with a hard substance; and this property, as also that of a high specific gravity, may be taken as rough tests of the purity of commercial lead. It is very malleable, so that it can be rolled out into thin sheets; but it is somewhat deficient in ductility, and therefore cannot be drawn into fine wire.

A very large quantity of lead is made into sheets for covering the flat portions and gutters of roofs, and also for lining cisterns. The lead is first cast into rectangular slabs, several inches thick, one of which is taken and rolled backward and forward between a pair of heavy iron rollers, fitted with reversing gear, until the thickness is considerably reduced; it is then divided into pieces, each of which is passed again through the rollers till it is brought to the required thickness. Lead is also largely manufactured into pipes, and this is done by using a hydraulic press to force it, when melted, through an iron mould, in the centre of which an iron mandrel or core is fixed. Shot is made from lead alloyed with a small quantity—rather more than one part to a thousand—of arsenic, which has the curious effect of rendering the globules more spherical.

Lead is not acted on by dilute sulphuric acid, and consequently immense chambers for the manufacture of vitriol are now constructed of it. Hydrochloric acid acts very slowly on lead, but nitric acid dissolves it readily, especially when diluted. Although ordinary hard water scarcely acts on this metal at all, yet pure soft water to a slight

extent does, and therefore some caution is necessary in using soft water which has been standing any length of time in a lead cistern, for cooking purposes. In certain alloys employed in the arts lead is an indispensable metal; thus, with antimony it forms type-metal; with tin, Britannia metal, pewter, composition metal for pipes, and solder. Much lead is converted into the carbonate (white-lead) for the use of painters, while a lesser quantity is made into red oxide, red-lead, or minium, as it is variously called, and likewise used as a paint, but also in the manufacture of flint-glass and glazes for pottery. Besides these, other compounds of lead are employed by dyers, calico-printers, and druggists.

In Great Britain, 69,037 tons of lead were smelted in 1871, which may be taken as nearly the average for a considerable number of years. Its value amounted to £1,251,815, or rather more than £18 per ton. In the same year, 65,167 tons, valued at £1,393,134, were imported, principally from Spain and Greece; while 44,787 tons, valued at £860,528 (some of it not being desilverised), were exported. Both the imports and exports of lead have increased of late. (In 1880, the total produce of lead in Britain was 57,000 tons, value £954,000.)

Zinc.

Although in Europe the distinctive properties of zinc were first described by Paracelsus, in the 16th century, yet it had been known and used in the East from an early period. The Romans were acquainted with the art of making brass—an alloy of copper and zinc—but this may have been obtained from smelting an ore containing the two metals, a practice not yet entirely abandoned. The two principal ores of zinc are blende, or sulphide of zinc—called by the miners 'black jack'—and calamine, or carbonate of zinc; the former, when pure, containing 67 per cent. and the latter, 52 per cent. of the metal; but, like most ores, they are rarely found pure. Blende is found in Wales, Cornwall, and Derbyshire; and calamine chiefly in Cumberland. On the continent, there are well-known localities for zinc ores, in Belgium, Italy, Silesia, Carinthia, and Spain, in the north-west of which large deposits of calamine were discovered a few years ago. Three distinct kinds of furnaces are in use for smelting zinc, namely, the English, the Silesian, and the Belgian, in all of which the metal is extracted by distillation, as it goes off in vapour at a bright red-heat. The last is now by preference used in England. It consists of a wide, but comparatively shallow arched chamber, with a fireplace along the bottom. The chamber is divided by shelves and upright pieces, into sixty or eighty pigeon-holes, each containing a carefully made fire-clay retort, with a clay condenser or nozzle, and a sheet-iron mouth-piece. The size of the retort is about three feet six inches long, and eight inches in diameter, and each receives a charge of ground and roasted ore, mixed with small-coal free from sulphur. The furnace being in action, carbonic oxide gas soon forms, and burns with its characteristic blue flame at the mouth of the retorts, which after a time disappears, and the white fumes of zinc then begin to appear. The iron mouth-pieces are now put on, and the furnace kept steadily going for about six hours, when the melted zinc which has accumulated in the condensers of the retorts is withdrawn by a scraper, and cast into cakes or ingots.

Zinc is of a bluish-gray colour, is comparatively soft, though much harder than lead or tin, and presents a crystalline fracture when broken. It

Fig. 7.—Zinc Retort, with Clay and Zinc Nozzles.

is rather brittle at ordinary temperatures, but it was discovered early in this century that, if heated to between 200° and 300° F. its malleability and ductility were so increased that it could be rolled into thin sheets or drawn into fine wire. Since then, zinc has been gradually applied to a great many useful purposes, its use formerly being chiefly confined to form brass with copper. In moist air it takes on a superficial coating of oxide, eventually converted into carbonate, which seems to protect the body of the metal from further oxidation. This property gives it a particular value for roofing, spouting, skylight frames, and the like, for which it is now much employed. The so-called galvanised iron is merely iron dipped in melted zinc to protect it from rusting. Plates for engraving upon, light perforated screens, statuettes, and other ornaments of zinc, have of late years been extensively made. Oxide of zinc is used as a white paint, for which purpose it keeps its colour better, but has less body than white-lead. Some of the salts of zinc are used in medicine and the arts.

From the zinc ores raised in the United Kingdom in 1880, 7162 tons of zinc were obtained, the value of which was £123,544, and the mean price per ton for the year about £17, 5s. Our great supply of zinc is obtained from Belgium and the island of Sardinia, the former exporting it as metallic zinc, the latter as ore.

Aluminium.

This interesting metal was first isolated as a gray powder by Wöhler in 1828; but it was little known till the experiments of St Clair-Deville, in 1855, shewed that it could be prepared on a large scale, and in a compact form, without much difficulty. Clay and felspathic minerals are largely composed of alumina, or the oxide of aluminium, and therefore substances which might be used as an ore of the metal are abundant. But aluminium has of late been made chiefly from bauxite, a mineral found in France, and consisting chiefly of alumina and oxide of iron. From this, by certain processes, a double chloride of aluminium and sodium is prepared, which is then heated in a reverberatory furnace, with fluxes and metallic sodium added. The sodium seizes the chlorine in combination with the aluminium, and the latter thus liberated falls to the bottom of the fused mixture.

Aluminium is a remarkably light metal, its specific gravity being only 2·6, or about one-fourth the density of silver. Its colour is white, with more of a bluish tendency than silver; and, so far as is yet known, it is not in the least tarnished, even by impure air. It is malleable and ductile,

as well as highly sonorous. The applications of aluminium have not as yet been so extensive as one would expect from its valuable properties. It is employed for small works of art and jewellery, but is less used by itself than in the form of an alloy with copper. This alloy, which is remarkably like gold in appearance, was discovered by Dr Percy of London, and consists of copper, with from 5 to 10 per cent. of aluminium. It is nearly as hard as iron, with a tensile strength between that of iron and steel. Aluminium-bronze, as this valuable compound is called, is largely used for decorative objects, watch-chains, pencil-cases, and small articles of that nature. A new method of producing aluminium in large quantities, and at one-tenth of its former price, was patented in 1882.

Tin.

England was famous for its tin in the days of the ancient Phœnician traders, and not far from half of all the tin produced in the world is obtained in Cornwall still. About the same quantity is procured from the ores of Southern Asia, found in Malacca, Banca, and Billitan. Bolivia and Peru furnish a much less, though still considerable supply; but the produce of other countries is insignificant. There is but one ore of tin, called tin-stone, cassiterite, or peroxide of tin, found in sufficient quantity for metallurgical purposes, and it contains, when pure, 78·6 per cent. of the metal.

The tin ore is stamped to powder and repeatedly washed, its high density enabling it to be thus readily separated from earthy impurities; but certain metallic minerals usually associated with it, such as copper and arsenical pyrites, galena, and tungsten, which have nearly the same specific gravity as tin ore itself, cannot be separated by washing. These, accordingly, require to be removed by combined roasting and washing processes before the ore can be smelted. In the roasting, which is done in a reverberatory furnace, the sulphur and arsenic are volatilised, oxides of other foreign metals are formed, and the sulphide of copper is converted into sulphate. The second washing removes these oxides mechanically, and dissolves the sulphate of copper. When the arsenic is saved, the flues are connected with condensers in which it is collected, and afterwards resublimed to form the 'white arsenic' of commerce.

The tin ore being prepared as above described, it is then smelted at a high temperature in a reverberatory furnace. Rather more than 20 cwt. are introduced at a charge, mixed with one-sixth part of small-coal, and occasionally also with a little slaked lime or fluor-spar, to serve as a flux for the siliceous impurities. In about six or eight hours the tin is reduced, and is run into cast-iron pans, from which it is ladled into ingot-moulds. It is afterwards refined by the process of *liquation*.

Tin is a white, beautiful metal, slightly inclining to yellow. It is rather soft, has a high lustre, and is not easily acted on by the air at ordinary temperatures; nor is it readily affected by moisture. It is so malleable that it can easily be beaten into foil not exceeding $\frac{1}{1000}$th of an inch in thickness; and at the temperature of boiling water it possesses considerable ductility. Nitric acid attacks it violently, but neither sulphuric nor hydrochloric acids act readily upon it. Of all the cheaper metals, tin preserves its cleanness and brightness best. It is consequently largely employed for depositing on the surface of other metals, as in coating thin sheet-iron to produce 'tin-plate,' in the 'tinning' of iron hollow ware, and various kinds of copper utensils. Lead pipes are sometimes coated internally with tin to preserve them from the action of soft water; and 'Albion metal,' so much used for coffin furniture, is formed of a layer of tin adhering by pressure to a layer of lead. Mirrors are made by coating glass with an amalgam of tin and mercury. With other metals it forms some valuable alloys, as bronze, gun-metal, bell-metal, Britannia metal, pewter, and solder. Purple of Cassius, a compound of tin and gold, gives a beautiful crimson colour to glass and porcelain. Metastannic acid (a hydrated oxide of tin) is used in the preparation of enamels, and under the name of putty powder it is in much request for polishing ornamental stones, as well as other substances. Both the chlorides of tin are extensively used by dyers and calico-printers.

While the total annual quantity of English copper ore has for a considerable number of years been gradually declining, the amount of tin ore mined in Cornwall and Devon has been gradually increasing. The value of metallic tin, too, although fluctuating from year to year, has been, on the whole, rising; and for the first half of the year 1872, it had risen to an average of £153, 18s. per ton, the highest price reached during the present century. In the year 1871, the British produce of tin ore (black tin) was 16,898 tons, yielding of metallic (white) tin 11,320 tons, the value of which amounted to £1,556,557. During the same year, 8583 tons of tin, chiefly from the Straits Settlements of British India, were imported into the United Kingdom, while 7770 tons were exported. In 1880, 8918 tons of tin were produced in Britain, value £813,767. One curious fact is, that from 60 to 80 tons are annually consumed in Birmingham in the manufacture of coffin-lace.

Mercury or Quicksilver.

Mercury, as well as some of its compounds, was known to the ancients. Native mercury is obtained in globules disseminated through its ores, but it is somewhat rare. A few native amalgams also occur, but the great source of the metal commercially is cinnabar or sulphide of mercury, a heavy, bright-red substance, identical in composition with the pigment vermilion. It contains 86·2 of mercury, and 13·8 of sulphur, when pure, but it frequently contains admixtures of other minerals, especially such as contain copper, iron, or aluminium. The most important European mines are those of Idria, in Illyria, and those of Almaden, in Spain; the former, according to an estimate made a few years ago, yield annually 250, and the latter 1000 tons of mercury. The Idrian mines were discovered in 1497, those of Almaden long before the Christian era. Cinnabar is found at several other places in Europe; in the Ural and Altai Mountains; largely in China; as also in Mexico, Chili, and Peru. In recent years it has been extensively mined in California and Idaho.

Mercury is extracted from cinnabar (sulphide

of mercury) by several processes, all of which have for their object the removal of the sulphur and the distillation of the liberated quicksilver, in a furnace with several condensing chambers. Simple roasting will eliminate the sulphur, or it can be removed by the use of fluxes as lime or iron scales. The mercury is afterwards purified from foreign metals by redistillation, either alone, or with one-tenth of its weight of cinnabar. Mercury is known to be pure by its not yielding any black powder when agitated in a bottle with dry air; by its not dragging a tail, when run down a gentle incline; and by certain chemical tests. At ordinary temperatures mercury is liquid, but it freezes between 39° and 40° F, in which state it can be cut with a knife, and is malleable and ductile. In lustre and colour it resembles polished silver, and remains untarnished for any length of time in air, oxygen, and many other gases. Nitric acid, both when cold and hot, dissolves mercury; strong sulphuric acid also acts upon it when heated; but hydrochloric acid has no action upon it in either condition. Mercury is employed, as already stated under Gold and Silver, in extracting these metals from their ores by amalgamation. Many of its amalgams, as the alloys of mercury are termed, are employed in the arts. Those of gold and silver are used for gilding and silvering, but much less than formerly, since the introduction of the electro-deposit process. The use of tin-amalgam in 'silvering' mirrors has been already referred to. Several others are used by dentists for stopping teeth, the chief being an amalgam of tin and cadmium; another of tin, silver, and gold; and another of copper. Sodium-amalgam is now often used instead of quicksilver alone in the treatment of gold ores. Metallic mercury is of great service in the construction of barometers and thermometers, as well as many other pieces of philosophical apparatus. The beautiful pigment vermilion is an artificial sulphide of mercury prepared by triturating the metal with about one-sixth of its weight of sulphur during the application of a gentle heat. The mass is then sublimed and afterwards levigated with water. Corrosive sublimate or perchloride of mercury is used as an antiseptic for dry-rot in timber, and for mildew in ropes and sails. It is the most powerful agent for destroying moth-eggs in animal substances. Both it and calomel, the chloride, are used in medicine. It is as well to state that corrosive sublimate especially is very poisonous.

Antimony.

Basil Valentine discovered this useful metal about 1490. Antimony is found native, but for commercial purposes it is obtained almost entirely from stibnite or gray antimony, a crude sulphide of the metal. This ore, although found in Cornwall, Dumfriesshire, and Ayrshire, is not mined in Great Britain. Considerable quantities are, however, imported into the United Kingdom, chiefly from Borneo, although it is found elsewhere. Crude antimony, or regulus of antimony, is the native sulphide after it has been melted in a retort or reverberatory furnace, and the earthy impurities, which float on the surface, removed. From this purified sulphide the metal is obtained by heating it with carbonate of potassium. Metallic antimony is now, however, produced in some localities direct from the ore by smelting it in crucibles with alkaline slag and scrap-iron.

Antimony is scarcely ever used alone in the arts, but its alloys and compounds have several important applications. A good type-metal is formed of 6 parts of lead and 2 of antimony, but the proportions vary, and sometimes bismuth is added. Common stereotype metal consists of 6 parts of lead and 1 of antimony, and an alloy of these two metals also yields the plates on which music is engraved. Britannia metal, it is stated by a large Birmingham manufacturer, usually consists of 90 parts of tin, 8 of antimony, and 2 of copper, bismuth being now rarely added. In these alloys, the use of the antimony is to impart hardness, and in the case of type-metal it also confers the property of expanding during solidification, thus causing the types to take a very sharp impression from the moulds into which they are cast. Antimony itself, in its ordinary commercial state, is a beautifully crystalline metal, bluish-white in colour, and so brittle that it can easily be reduced to powder. It does not oxidise in either moist or dry air, nor do the mineral acids in their simple state attack it very readily. Antimoniate of lead forms the useful pigment Naples yellow; and yellow colours on porcelains and enamels are likewise formed by oxide of antimony along with oxide of lead or oxide of zinc. The use of antimony for pottery glazes is very ancient, it being found on Assyrian and Babylonian ware. Some compounds of antimony are valuable medicines.

Arsenic.

The compounds of arsenic have been long known, although the metal itself was not discovered till 1733. We have already seen that arsenious acid, the chief form in which arsenic occurs in commerce, is obtained as a secondary product in the smelting of tin. It is also obtained as a by-product in reducing cobalt and nickel ores. Many ores, indeed, contain arsenic in notable quantity, and large quantities of it are annually wasted in roasting pyrites for the manufacture of sulphuric acid. Native arsenic occurs to a not inconsiderable extent in Bohemia, Saxony, and other places in Central Europe, and so also does arsenical pyrites, the sulphide of iron and arsenic. Metallic arsenic is obtained either from arsenical pyrites or arsenious acid by sublimation in close vessels so as to exclude air. Arsenious acid, or the trioxide of arsenic, called also white arsenic, or simply arsenic, when produced directly from arsenical substances, is obtained by heating them in a subliming furnace connected with a series of condensing chambers, termed a 'poison tower.' The fume which condenses in the chambers is an impure arsenious acid in the form of a gray powder. This is refined by repeated sublimations in cast-iron pans surmounted by metal cylinders, and finally converted into arsenical glass, which, when pounded, furnishes the arsenious acid of commerce. When first produced, this glass is a beautiful substance, clear and colourless, but becoming opaque on keeping. The workmen who remove the arsenious acid from the flues, as well as those who grind and pack it, are liable to a disagreeable eruption of the skin. All the operations connected with so highly poisonous a substance as white arsenic are necessarily dangerous,

and in some the workmen require to protect the face with a towel, and stop up the nostrils with cotton-wool.

Two sulphides of arsenic, namely, realgar (disulphide) and orpiment (trisulphide), occur native; but, for commercial purposes, they are prepared artificially by heating together arsenious acid and sulphur, or by their sublimation. Realgar is of a beautiful red colour, and, when refined, forms red arsenical glass. Cups, teapots, and similar articles are made of it by the Chinese; and it is one of the ingredients in *white Indian fire*. Orpiment is the colouring substance in king's yellow.

Like antimony, metallic arsenic is very brittle, and may be easily reduced to powder in a mortar. When heated, it passes at once from the solid state into vapour without fusing. It performs an important function as an alloy in certain metallurgical operations, but the metal is not used for any purpose by itself. Several compounds of arsenic are, however, extensively employed. Combined with copper, it forms *Scheele's green*, and with acetic acid in addition, *emerald green*, both beautiful colours used by painters, paper-stainers, and dyers. Arsenate of sodium has been much used of late years as a dung-substitute in calico-printing. Arsenious acid in minute quantities is a useful medicine. It gives an opaque white colour to flint-glass, so as to make it resemble porcelain. A great deal of it has been consumed of late years in the manufacture of rosaniline. Another use of it is found in preserving seeds and fruits. For such purposes as poisoning rats, it can now only be purchased, under certain restrictions, coloured with indigo.

Bismuth.

Bismuth is nearly all obtained from the native metal, which generally occurs in veins in crystalline rocks, associated with ores of silver, cobalt, lead, and zinc. It is chiefly found in Saxony and Bohemia, but it also occurs in Norway and Sweden, as well as in Cornwall, Devonshire, and Cumberland, in England. It is likewise obtained in South America and the United States, but is not an abundant metal.

Bismuth is extracted from the ores and minerals which usually form its matrix, by simply heating them on a hearth till it melts and runs out, its point of fusion being about 260° C. Within the last ten or twelve years, bismuth has risen greatly in price, being now more than one-third the value of silver. Some artificially crystallised specimens of the metal, with fret-like modifications of cubes, are objects of great beauty.

There are not many uses to which bismuth can be applied, though some of them are important. It increases very much the fusibility of other metals with which it is alloyed, and for this reason it is used in the formation of pewter, solder, and type-metal. Several alloys of bismuth, lead, and tin, called fusible metal, melt under the temperature of boiling water. Nitrate of bismuth is used in the manufacture of white sealing-wax, and in medicine. Formerly, it was extensively consumed as a cosmetic.

Cobalt.

The two closely allied metals, cobalt and nickel, can scarcely be distinguished from each other by the eye, and their ores are nearly always found together. Both much resemble iron in appearance, as well as in hardness and tenacity, but are whiter in colour. Although cobalt is not employed in the metallic state, yet its property of forming blue colours when in combination with other substances, especially silica and potash, confers much value on its compounds. *Smalts* and *zaffre* are both the powder of cobalt glass. A mixture of alumina and phosphate of cobalt, heated to redness, yields a fine blue like ultramarine. Since the discovery, about thirty years ago, of Mr Askin's process for the separation of cobalt from nickel, oxide of cobalt has been largely made in Birmingham, for the purpose of imparting a blue colour to pottery and glass. Curiously enough, his process did not aim at this application of the oxide at all, being used at first simply to eliminate the cobalt from the nickel, as its presence was injurious to the latter. For some time, accordingly, it was looked upon as a waste product; but on its value as a colouring substance being discovered, potters bought it at the rate of two guineas a pound, thereby amassing a large fortune to the makers. Its price is, however, much lower now.

Nickel.

The name of this metal is from the German, and signifies something of little worth. Nickel is, however, both an important and an interesting metal. It first began to be made on a manufacturing scale about forty years ago, Mr Askin of Birmingham having then discovered an efficient way of refining it. Its chief ore is *kupfer-nickel*—'false copper'—so called by the German miners from its resembling but not yielding copper. When pure, it consists of arsenic 56, and nickel 44, and is found in Saxony and Hungary, occasionally in Cornwall; and of late years some has been raised from the old Hilderston silver mine, near Bathgate, in Scotland. Another ore, a sulphide of iron and nickel, has been largely worked in Norway, and, to a less extent, near Inverary, in Scotland. Nickel also occurs as a constituent of many complex ores. The processes employed for the reduction of the metal are, for the most part, kept secret.

Pure nickel is a hard, not easily tarnished metal. Its whiteness is between that of silver and polished steel. It is malleable and ductile, and has a higher tenacity than wrought-iron, but has hardly as yet been employed alone, except in a recent application as an electro-deposit on brass or iron furniture, for which its hardness and non-liability to tarnish render it very suitable. Nickel is most in demand to form the important alloy known as German silver, of which a vast number of articles, such as table-plate of all kinds, are now made in Birmingham. These are very often plated with silver, for which this alloy is singularly well suited. It consists of copper, nickel, and zinc in various proportions. Other alloys of nickel are used in the coinage of some foreign countries, and the late Master of the Mint was strongly in favour of its being introduced into the new copper coinage of Great Britain. A new alloy, formed of 1000 parts of copper, 700 of nickel, and 50 of tungsten, under the name of 'min-argent,' has of late been extensively employed in Paris as a substitute for silver.

Platinum.

A Spanish traveller, named Anton Ullsa, appears to have been the discoverer of platinum. He found it in Peru in 1735 or 1736. It was first found in Russia in 1822, but it was years after this even before any exact knowledge of it was obtained. Platinum is always found in the metallic state, although never pure, being invariably alloyed with one or more of the rare metals—rhodium, iridium, osmium, palladium, and ruthenium. Copper and iron are likewise usually present. It occurs in the form of flattened grains in alluvial soil; more rarely it is found in lumps, the largest yet met with being the nugget from the Ural chain, in the Demidoff collection, which weighs 21 lbs. The chief supply of platinum is derived from these mountains. Brazil, Peru, New Granada, California, and Borneo also furnish supplies.

Until recently, platinum could only be prepared in a state for use by Wollaston's process, in which it is first obtained in the spongy state, and afterwards consolidated by welding. The melting-point of platinum is so high that, a few years ago, the fusion of a globule was looked upon as a feat. Great astonishment was therefore occasioned by the appearance, in the International Exhibition of 1862, of an ingot weighing two and a third hundred-weight, and bearing unmistakable evidence of its having been melted. Its value was £3840. The merit of providing a means for fusing such large masses of platinum is due to the French chemist Deville, and the process is carried on in a furnace in which the heat is produced by jets of coal-gas and oxygen. Previous to smelting, the ore is mixed with a small quantity of lime, which is also used as a lining to the furnace. During the operation, the impurities are partly imbibed by the lime, partly volatilised, and the platinum is extracted from the remainder by aqua-regia.

Platinum is the heaviest substance known, it is one of the most difficult to fuse, and no single acid has any action upon it. It is white in colour, and has a high lustre when polished, although inferior to silver in brilliancy. It does not oxidise in air at any temperature. In ductility and tenacity platinum resembles iron, and is of about the same hardness as copper. The great use of platinum is in the construction of crucibles, evaporating dishes, and other apparatus for chemical research; and for stills and other vessels used in the manufacture of sulphuric acid, and the refining of gold and silver. It is doubtful, indeed, if the great progress made in scientific chemistry during the present century could have been accomplished without platinum. Formerly, a piece of spongy platinum, which has the singular property of becoming red-hot in hydrogen, was used, together with a jet of that gas, to produce a light. Platinum coins were for some time current in Russia, but are now abandoned. The value of the metal is about five times that of silver.

Manganese.

Like a few other metals, manganese is as yet of no service alone in the arts, but plays an important part in some alloys, and especially when mixed to a small extent with some kinds of steel. Pure manganese is white, with a faint reddish tinge, and is very hard and brittle. It takes on a fine polish, and does not tarnish in air. Its chief ore is the black oxide or pyrolusite, which is a tolerably abundant substance. Large quantities of this oxide are imported into England for the manufacture of bleaching-powder, the total annual consumpt being estimated a few years ago at 11,450 tons. It is also used in the manufacture of both clear and coloured glass.

Chromium.

It is not long since metallic chromium was obtained in a state of purity. It is remarkably hard, difficult to fuse, and costly to prepare. Only the compounds of chromium are turned to any useful purpose, and these are chiefly prepared from chromite or chromate of iron, which is found in the Shetland Islands, Norway, Spain, and several other countries. Chromate and the bichromate of potassium, and the chromate of lead, are used in dyeing, calico-printing, and for other purposes. The green oxide of chromium is a valuable material in enamel-painting, as it is not decomposed by heat.

Magnesium.

Of late years this metal has been made on a considerable scale from magnesium carbonate. It is a beautiful silver-white metal, becoming coated with a crust of magnesia when exposed for a short time in moist air. It burns at a red-heat with a dazzling white flame, and on this account it has been a good deal used for taking photographs where sunlight cannot penetrate.

Cadmium.

Both cadmium and magnesium closely resemble zinc in their properties, and the former is also commonly associated with it in the ore. Cadmium could be produced at a comparatively low price if it were much in demand, which as yet is not the case. Its use in dentistry has already been referred to under Mercury, but it is chiefly consumed in the state of sulphide of cadmium, which furnishes the painter with a beautiful and permanent yellow pigment.

Palladium—Iridium—Osmium.

Palladium is a rare metal, resembling platinum in appearance, but not nearly so heavy. It forms a fine white alloy with silver, which, as well as an amalgam of the metal, has received some useful applications. Iridium is a hard, brittle metal, fusible with great difficulty, the oxide of which gives an intense black colour to porcelain. Osmium is another rare, highly infusible metal, the most refractory, indeed, of all. A native alloy of osmium and iridium occurs, which is the hardest metallic substance known, and used to tip the ends of the so-called gold pens,

THE STEAM-ENGINE.

BEFORE entering into the history or practical details of our subject, it will be necessary to make some general remarks on the nature and properties of steam, and on the value of the different kinds of fuel used in producing it. These being understood, the reader will be able more intelligently to follow the descriptions of the steam-engine itself in its construction and operation.

Steam-engines in their infancy were always known as 'fire' (that is, *heat*) engines; and in point of fact the older term is the more correct, because the water or steam is only used as a convenient medium through which the force which we call heat is made to perform the required mechanical operations. For general remarks on the theory of heat, &c. our readers are referred to No. 13. In this article, we shall only touch on those points specially connected with our subject.

Water is one of the few natural substances which exist in the three conditions, solid, liquid, and gaseous, within ordinary limits of temperature. That which causes ice to become water, or water steam, or, conversely, that which causes steam to liquefy into water, or water to congeal into ice, is simply the addition or abstraction of a certain quantity of heat. In other words, when a pound of ice becomes a pound of water, while the apparent difference is only in molecular condition, the *real* difference is, that there is added to the water a large and measurable quantity of an imponderable and impalpable force which we call heat, the nature of which is only now beginning to be understood. We have used the word *impalpable* advisedly, because the water will be of exactly the same temperature immediately after its liquefaction as before, so that a thermometer placed in it would indicate 32°, precisely as it would have done had it been previously placed on the ice. Notwithstanding this, the water contains far more heat than the ice.

Heat exists in two forms, one of which sensibly affects us with warmth or cold, and is called *sensible* heat; while the other affects only the particles of the body in which it exists, loosens or altogether destroys their mutual attractions, and is called *latent* heat. Our present system of measuring heat, whether sensible or latent, as temperature, arises from a perpetuation of old and mistaken ideas of its nature. It is now universally recognised to be *a force*, and to be capable of measurement in 'foot-pounds,'* just as much as the blow of a steam-hammer. In modern scientific works, quantities of heat are now stated generally either in foot-pounds or in 'thermal units,'† instead of in degrees of temperature. Modern investigations have established the fact, that the force or energy stored up in one thermal unit is exactly equal to, and convertible into 772 foot-pounds of work. This work is therefore called the *mechanical equivalent* of one thermal unit.

The temperature at which water becomes ice has been fixed as a point on Fahrenheit's scale at 32°, and that at which it gives off vapour of the same density as the atmosphere at 212°, the intermediate stages of sensible heat being arbitrarily divided into 180 equal parts. 212° F. is commonly called the boiling-point of water. This expression, however, must be understood only with the limitation given above, and not as being *the* point at which water becomes steam. In this latter sense, every point is a boiling-point, for all water, snow, and ice, at every temperature, is giving off vapour into the air. The reduced temperature does not prevent the formation of steam, but only decreases its density. Thus at 212° F. water will give off steam of a density equal to that of the atmosphere, or, in other words, exerting a pressure in every direction equal to 14·7 lbs. per square inch. But if water be exposed to the same temperature in a closed space, the remainder of which is filled with air already saturated with such steam, no more vapour will be given off. The tendency of the particles of water to fly apart is exactly balanced by the pressure of the vapour on its surface. Similarly, water at 32° F. will give off vapour of a pressure equal to 0·085 lbs. per square inch, unless the air above it is already saturated with vapour of that density. It is a most remarkable fact, that while no atmospheric pressure can prevent the water or ice passing into vapour, the previous presence in the air of vapour of the required density (even when so small as in the last-named instance) entirely stops it.

For every degree of sensible heat, there is a corresponding density of steam produced. This steam contains a fixed amount of latent heat, and exerts a certain uniform pressure on every side of any vessel in which it may be contained. The following table shews the relation between these different values for steam of several different temperatures, and should be carefully studied:

T.	*p.*	L.	H.	*h.*	V.
32°	0·085	1091·1	842872	0	3390·0
104°	1·06	1113·1	859793	55612	312·8
158°	4·51	1129·5	872484	97411	80·02
212°	14·7	1146·1	885175	139363	26·36
248°	28·83	1157·0	893635	167460	14·0
293°	60·4	1170·7	904211	202798	6·992
356°	145·8	1189·9	919017	252658	3·057
401°	250·3	1203·7	929593	288634	1·838

T, Temperature (or boiling-point) in degrees Fahrenheit. This corresponds to the sensible heat of the steam.

p, Pressure in pounds per square inch of the vapour at that temperature.

L, Total heat of the vapour at that temperature in degrees Fahrenheit, from 32°.

H, Total heat, expressed in foot-pounds, required to raise 1 lb. of water from 32° to the given temperature T,

* A foot-pound is a familiar standard of work among engineers, and means a force equal to that which would raise one pound avoirdupois one foot high.

† A thermal unit is the amount of heat necessary to raise through 1° F. the temperature of one pound of pure water at or near its temperature of maximum density—namely, 39·1° F.

and to evaporate it at that temperature (= mechanical equivalent of the *total* heat of 1 lb. of steam at T).

h, Heat in foot-pounds required to raise temperature of 1 lb. of water from 32° to temperature T (= mechanical equivalent of the *sensible* heat of 1 lb. of water or steam at T).

V, Volume in cubic feet occupied by 1 lb. of steam.

$H - h$, Latent heat of 1 lb. steam at T in foot-pounds.

H; *h*; or $(H - h)$, divided by 772, will respectively give the total, sensible, or latent heat in thermal units.

The heat in degrees Fahrenheit is given according to Regnault's hypothesis.

Several of the properties possessed by steam render it peculiarly suitable for use as a source of motion in prime movers. Among them are its elasticity and its easy convertibility from a gaseous to a liquid state. The first of these manifests itself in the tendency of steam, in common with other gases, to expand indefinitely, undergoing at the same time a corresponding diminution of density or pressure. In obedience to a law known as Mariotte's law (from the name of its discoverer), the density or pressure of steam varies inversely as its volume. This means that if a cubic foot of steam be allowed to expand itself into a space of two cubic feet, its pressure will be halved; if into ten cubic feet, its pressure will be only one-tenth, and so on. In speaking of pressure in this article, we shall mean always (unless the contrary is stated) pressure above the zero of pressures, or a perfect vacuum, and *not* above the pressure of the atmosphere.

The easy convertibility of steam into water is a matter of great importance in relation to the economy and efficiency of engines. The reason of this will be found further on in the explanation of the theory of condensing engines; we may merely say here, that by the use of condensers much power is gained to the engine with scarcely any extra cost, which otherwise would be entirely thrown away.

Having now given some idea of the nature of heat and the properties of steam, we shall proceed to shew the way in which these are utilised by the engineer in the steam-engine. As will be hereafter explained in detail, the common mode of employing steam in an engine is by causing it to press alternately on the two surfaces of a movable diaphragm or piston inclosed in a fixed, steam-tight, cylindrical box. In fig. 1, A is the piston, and B a section of the box. The piston, by means

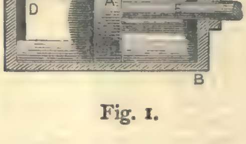


Fig. 1.

of a rod E, passing through the end of the box, is made to communicate motion to the rest of the machinery. The steam is first admitted to one end of the cylinder through an opening D, and forces the piston along to the other end. The current of steam from the boiler is then allowed to pass into the other end of the cylinder through the opening C, and forces the piston back again to its original position, and so on. But it is obvious that while this return-motion is going on, the steam previously admitted at D must be allowed some exit, or the piston could not be forced back. The manner of this exit constitutes the difference between the two principal classes of engines, according as the steam is allowed simply to rush out into the atmosphere, or is conducted into a separate vessel, and there 'condensed.'

The simplest way in which steam can be used in a cylinder is at the same time the most wasteful. It consists in filling each end of the cylinder alternately full of steam direct from the boiler, and having the full boiler pressure, and thus forcing the piston along in exactly the same way as that in which it would have to be forced were water the fluid used instead of steam. We have said this is wasteful; let us examine the reasons. If we imagine the cylinder to have a capacity of 7 cubic feet, then, if it be filled entirely with steam from the boiler at 60 lbs. pressure, it will contain just one pound-weight of steam.* The total heat in this pound of steam, as given in the table, is equivalent to 904,211 foot-pounds of energy. When the piston A has reached the end of its stroke, the steam contained in the cylinder is thus in itself a great storehouse of work. But instead of utilising this force, at the moment when the cylinder is full of steam, the opening C is put into communication with the boiler, the opening D with the atmosphere, and the steam immediately rushes out of the cylinder, and dissipates its contained energy through the air.

It must be remembered that although the steam, when allowed to go into the atmosphere, is immediately reduced to the pressure corresponding to the temperature of the air (which in ordinary cases would be only a fraction of a pound per square inch), still the full pressure of the atmosphere itself will always be acting on the back of the piston during its stroke, and that therefore, to find the force with which the piston is being pushed along, we must subtract that pressure from the steam-pressure. On the one side of the piston will be the atmosphere with its uniform pressure of nearly 15 lbs. per square inch, and on the other side the steam pressure of 60 lbs. The effective pressure thus will be 60 — 15, or 45 lbs. per square inch only.

Let us now consider the somewhat more economical case of an engine in which the steam is first used as described above, but afterwards, instead of being allowed to pass into the atmosphere, is conducted through a pipe into a closed vessel, and there condensed. The process commonly called condensation, and associated with the idea of liquefaction, consists in essence merely of the subtraction from steam of a portion of its sensible heat. This reduction of temperature has a double effect on the steam: first, the liquefaction of a part of it; and then, the reduction of the rest to the pressure corresponding to the reduced temperature. (It will be remembered that we have stated that steam exists at *all* temperatures.) It is not possible to do one of these things without the other, and this fact lies at the bottom of a correct conception of what is called by engineers a 'vacuum.' What is commonly called 'vacuum'

* These figures are near approximations only, as will be seen from the table.

simply means pressure less than the atmospheric pressure; and, in the case of steam-engines, a vacuum generally implies a pressure of between two and four pounds per square inch; that is, from a seventh to a fourth of the ordinary pressure of the air. The most common way of condensing steam is by bringing it into contact either with a jet of cold water, or with surfaces kept continually cool by a current of water. In either case, directly the steam is brought into contact with the water, or cooling surface, it transfers to it the larger portion of its sensible heat. During this process, the greater part of the steam is liquefied, and the remainder retains only such a pressure as corresponds to its greatly reduced temperature.

The advantages possessed by a condensing over a non-condensing engine will now be obvious. When the piston is being forced from C to D by steam entering through C, the force on the back of the piston resisting its motion in that direction, instead of being equal to the pressure of the atmosphere, is only the pressure of the steam in the condenser, or about 1 lb. per square inch. The net effective force is therefore 60 — 1, or 59 lbs., instead of 60 — 15, or 45 lbs. In actual practice, these figures would be modified, because, from various causes, such a low back-pressure as 1 or 15 lbs. above zero (in condensing and non-condensing engines respectively) is never obtained, but the principle remains the same.

We have supposed that our cylinder when full of steam contained just 1 lb. weight at 60 lbs. pressure. Let us now find out how much useful work this pound of steam has done for us, and we will then shew how the same weight may be made to do a great deal more, by utilising more of its great store of heat. Let us suppose that the area of the cylinder is 2 square feet, while its length (the stroke of the piston) is 3½ feet. It will thus have a capacity of 7 cubic feet, as before assumed. In the first case described, we should have a pressure of 45 lbs. per square inch exerted on an area of 288 square inches through a distance of 3½ feet. This is equal to 45,360 foot-pounds of work. In the second case, we have a pressure of 59 lbs. per square inch on the same area, and through the same distance. This is equal to 59,472 foot-pounds of work, or about $\frac{1}{18}$th of the total heat supplied by the fuel.* We may now proceed to examine the way in which the same weight of steam, generated by the consumption of an identical weight of fuel, may be made to perform many times more work by 'working expansively.'

We have already said that one of the properties of steam is a tendency to expand indefinitely. We also mentioned and explained the law that its pressure varies inversely as its volume. We will now describe the way in which this is taken advantage of by the engineer. If we have a cylinder of the same area as before, but of twice the length, but only intend to admit one pound of steam into it at a time, it will be necessary, when the piston has travelled 3½ feet of its stroke, to shut the entrance valve, so as to prevent more steam entering; this is called 'cutting off' the steam. The piston, however, still continues its motion in the same direction as before, propelled by the internal separative energy among the particles of steam. But as it is pressed forward, the space occupied by the steam is always increasing, and its pressure always decreasing in proportion, until at length, when the piston has reached the end of its stroke, the steam occupies exactly double its original volume—namely, 14 cubic feet, and is reduced in pressure to half its original pressure—namely, to 30 lbs. per square inch. We have thus during the first half of the stroke a constant pressure on the piston of 60 lbs. per square inch, and during the second half a pressure gradually decreasing from 60 to 30 lbs. The *mean* pressure during this second half of the stroke will be found on calculation to be almost exactly 40 lbs. Let us now in the same way as before see what work we have been able to get out of our pound of steam by expanding it in this way. In the first half of the stroke we have 59,472 foot-pounds of work exactly as before, and then we have in addition a mean pressure of 40 — 1, or 39 lbs. per square inch exerted over 288 square inches for a distance of 3½ feet. This equals 39,312 foot-pounds, making a total of 98,784 foot-pounds of work obtained from the steam which only gave us 59,472 before. The economy of working expansively, however, goes much further than this. If the cylinder had been four times its original length, and the steam had been cut off at the same point as before (which would then be quarter instead of half stroke), we should have obtained from the 1 lb. of steam 144,345 foot-pounds of work. If we had gone still further, and expanded the pound of steam into eight times its original volume, we should have obtained no less than 179,984 foot-pounds of work, which is more than three times as much as at first.* All modern engines are worked more or less on this principle of expansion, and the general tendency seems to be every year to adopt higher initial pressures, and larger ratios of expansion.

Fuel.—We must now go back a little, and consider the relative qualities of different fuels, and the economical effects produced by their combustion. The principal constituents of all substances used for fuel are carbon and hydrogen. They mostly contain also a small amount of oxygen, and a considerable percentage of incombustible matter called *ash*. Speaking generally, that fuel is the best which contains most carbon, and least of the other constituents. The great heat developed by the combustion of coal is the result of the chemical combinations which occur during that combustion, for it is now a well-ascertained fact that all bodies in the process of chemically combining with others liberate heat, just as in decomposing they absorb it.

When coal undergoes combustion, the action which takes place is as follows: The fuel is first decomposed into two parts, solid and gaseous; the former remains on the grate as incandescent coke, and gradually combines with the oxygen of the air; and the latter consists of free hydrogen and the hydrocarbon gases. The hydrogen in these gases, having a much greater affinity for oxygen than for carbon, quickly rids itself of the

* For simplicity's sake, we have here assumed that the water in the boiler has to be raised from 32° to 292°, and evaporated at that temperature. If the water were supplied at 212°, then the work done would be about $\frac{1}{15}$th instead of $\frac{1}{18}$th of the total heat.

* In actual working, owing to various causes—such as imperfect action of the valves, radiation from the cylinder, bad vacuum, &c.—the work obtained from the steam is not more than ·65 to ·75 of that given in this paragraph.

latter, and combines with the former, which it takes from the air. This combination generates intense heat, which is freely communicated to the carbon particles just disengaged from the hydrogen, and at this temperature the carbon is able to combine with the oxygen to form carbonic acid. The efficiency of the combustion depends mainly on the completeness of this operation, for should the carbon particles not come in contact with the oxygen until they have lost temperature, they cannot combine, and will consequently pass away as black smoke; or if the supply of air is insufficient, carbonic oxide will be formed, and this combination yields only one-third the heat produced by the production of carbonic acid.

The standard used to compare the evaporative power of different fuels is the number of pounds of water one pound of each of them will evaporate. The water is supposed to have been previously heated to 212°, and to remain at that temperature during evaporation. The *theoretical* evaporative power of 1 lb. of average coal (according to this standard) is 14½ lbs. of water, and of 1 lb. of average coke, 13¼ lbs. The *actual* evaporation obtained varies very much, being dependent on the form and arrangement of the boiler and flues, the quality of fuel, and the care and attention of the stoker. In ordinary factory boilers, it is often as low as 6 or 7 lbs.; in locomotive and marine engines, from 9 to 10 lbs. We have seen, however, from 12 to 13 lbs. water evaporated by first-rate fuel in very good examples both of stationary and marine boilers. When small coal, or *dross*, is used in Cornish boilers of ordinary construction, the evaporation we have sometimes found to be as low as 3 lbs. of water per pound of fuel.

We have already said that steam is water (in a gaseous condition), plus a large amount of latent heat. The whole of this heat has to be communicated to it by the fuel, just as much as the sensible heat. The latent heat of steam at 212° is equivalent to about 996° F. The sensible heat, however, between 32° and 212° F. is only 180°, so that its latent heat is 5½ times its sensible heat above 32°. In other words, if any given weight of fuel be required to raise a certain quantity of water from 32° to 212°, then it will require 5½ times that quantity to convert the water into steam at that temperature.

We have above referred to the oxygen of the air as being an essential to combustion. This gas constitutes about one-fifth by bulk of the air; and as 1 lb. of fuel requires (on the average) 2½ lbs. (or 30 cubic feet) of oxygen for its perfect combustion, about 150 cubic feet of air must be admitted into the furnace for each pound of fuel burned. This is the amount chemically required, but as much air passes through the furnace without assisting the combustion, it is found necessary in practice to admit 50 or 100 per cent. more.

The proportion which the area of the fire-grate bears to the total heating surface, as well as to the amount of fuel consumed, is of the utmost importance to the efficiency of the boiler. The boilers of Cornish engines have a large grate surface, and burn the fuel very slowly, the lowest consumption reached being about 4 lbs.* coal per square foot of grate per hour. Ordinary factory boilers burn about 15, and marine boilers about 20 lbs. coal per foot of grate per hour. The draught induced by a chimney does not admit of a larger consumption than about 30 lbs.; but in locomotive boilers, where there is an artificial draught, small grate surface, and very quick combustion, 70 or 80 lbs. of fuel are commonly burned, and the consumption is sometimes far greater. With grates not burning more than 20 lbs. of coal, the whole of the air is admitted through the spaces between the fire-bars; but always in locomotives, and generally in marine boilers, a certain amount of air has to be admitted above the bars. As long as the boilers are properly designed and proportioned, there seems to be no difference in economy between fast and slow combustion; but one is more convenient in some cases, and the other in others, and the particular circumstances of each case decide the kind of boiler to be used.

Many experiments have been made to determine the relative economic value of the different kinds of fuel, and most valuable tables giving the detailed results of these are published. Welsh coals and anthracites stand at the head of British fuels, then Lancashire and Newcastle coals, and lastly Scotch coal; the last being deficient in carbon, and too rich in combined oxygen. The quality of coal used at a factory must be regulated by a consideration of its relative price and economic value. In steam-ships, superior qualities are generally used, because in them the space taken up by the coal is important, as every cubic foot saved from the coal-space can be made use of for cargo. Coke makes less smoke than coal, and is found more efficient where great local intensity of heat is required; coal, however, is better where the combustion has actually to be developed and carried on through flues, &c. at some considerable distance from the furnace.

We must now proceed to the consideration of the apparatus used in the generation of steam—namely, boilers and furnaces.

The oldest form of boiler used was probably the sphere; this was superseded by a cylinder set on end, and this further improved by making its bottom concave, and its top hemispherical. Watt's 'wagon' boiler superseded these, and continued in use for many years.

Smeaton seems to have been the first to make a boiler with an *internal* furnace, although his arrangement has long been superseded. As the working steam pressures came to be increased, it became evident that that form of boiler which required the fewest internal stays to prevent its bursting had many advantages over any other. The spherical form is the strongest of all, but has the disadvantage that the heating surface is very small indeed compared to the volume of water which it holds. Next to the sphere (as to strength against bursting) comes the cylinder, and this form is now universally used for boilers that have to withstand any considerable pressure. Fig. 2 shews a section of a 'Cornish' boiler, an invention of Trevithick's which holds its ground to the present day, and seems likely to do so for many years to come. This boiler is simplicity itself, though heavy and bulky. With care, it can be made to give very good evaporative results; and having thus fair economy with maximum strength and simplicity, and minimum liability of getting out of order, as well as small first cost, it is preferred

* Some authorities state 2 to 2½ lbs., but this seems doubtful.

in most cases where space and weight are not matters of vital importance. It consists simply of a cylindrical shell, *aa*, inclosing a much smaller cylinder, *ff*, called a flue. The ends of the flue

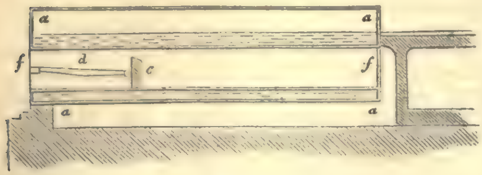


Fig. 2.

are open, but the space between it and the shell, which contains the water, is of course closed up. The fire-grate, *d*, is in the interior of the flue, and at the end of it is a brick bridge, *c*, made so as to cause the flame to impinge on the upper side of the flue. The boiler is set in brickwork; and the flame, passing out at the back end of the flue, is made to traverse the whole length of the boiler twice, through brick flues, before passing away to the chimney. Each boiler, when large enough in diameter, has two furnaces instead of one, which admits of a system of alternate firing, and conduces greatly to economy. In these boilers, the shell requires no stays, but the flat ends have to be strengthened by connecting stays, either to the shell, or from end to end. Cornish boilers are often strengthened, and their efficiency at the same time increased, by the insertion of cross tubes, called (after their inventor) 'Galloway' tubes. Mr Galloway's patent boiler is perhaps the most perfect modification of the Cornish boiler in use. It is similar in external appearance to a Cornish boiler, and has two internal furnaces. These, however, join in one just behind the bridges, forming a combustion chamber, where the gases are well mixed. The remainder of the length of the boiler is occupied by an elliptical flue fitted with Galloway tubes. The elliptical form is less strong of itself than the circular, but the cross tubes more than compensate for this.

In some boilers for stationary engines the flues terminate in a combustion chamber, and the gases are compelled to traverse a large number of horizontal tubes filling the space between the back of the chamber and the back of the boiler, in the same way as the tubes in the locomotive boiler hereafter to be described. These are called 'multitubular' boilers; they are very efficient steam generators, and take up less room than Cornish or Galloway boilers of equal power. Room, however, is not usually a very important object in such cases, and the greater cost of these boilers has prevented their coming into extended use.

There are very many patents for 'safety' boilers, the principle of whose construction is that they consist of a number of small pieces instead of one large one, so that the danger from explosion is reduced to a minimum, as any excessive strain which might blow up a large boiler, would relieve itself by simply breaking one of the pieces, which would be attended by inconvenience, but not with danger. The best known among these is perhaps Howard's boiler, but the public set their complication and liability to get out of order against their safety, and they do not seem to be making much way. A proper system of periodical inspection and cleaning should reduce—and to a great extent has reduced—the risk of boiler explosions to a minimum.

The peculiar form adopted in the boilers of locomotive engines will be found fully described further on.

In steam-vessels, an economical boiler is a necessity, as well as one which does not take up much space, and the multitubular form is therefore always adopted.

Fig. 3 shews an elevation and section of a marine boiler as made at present. As high pressures are now constantly used in steamers, the shell *aa* is made cylindrical, *b* is the furnace, *c* the fire-grate, and *d* a brick bridge; *e* is a combustion chamber or flame-box; *f*, *f*, the tubes through which the flame passes back to the front of the boiler; and *g*, the smoke-box, communicating with the funnel *h*. The line *kk* shews the ordinary level of the water in the boiler. In such a boiler as this, all the flat surfaces, such as the back of the shell and flame-box, have to be strengthened by stays.

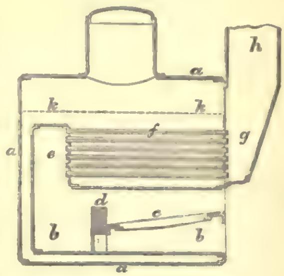


Fig. 3.

Boilers in the time of Newcomen and Smeaton were made of cast-iron, the only material available at the time, but one which was quite unsuitable for the purpose of resisting pressure. The inventions of the unfortunate Henry Cort in 1783, however, coming close on those of Watt, supplied the means of making wrought-iron boilers just when it became absolutely necessary to do so. Since that time, boilers have always been made of wrought-iron plates fastened together with rivets.

In order to induce such a draught through the furnace as to supply the fuel with sufficient air for its perfect combustion, the flues of all boilers communicate with a chimney or funnel. In certain cases in which it is not possible to make a chimney high enough to give sufficient draught, an artificial current has to be induced, as by the steam-blast in the locomotive.

Having mentioned the principal varieties of boilers now in use, we proceed to describe their principal appendages or 'mountings.' First among these comes the safety-valve, the duty of which is to allow the steam to escape when it reaches a certain pressure, and thus to prevent undue strain on the boiler-plates. Fig. 4 shews in outline the principle of this valve: *aa* is a dome on the top of the boiler-shell; *b* is a conical brass valve resting on a seat, which has been smoothly bored for its reception; *e* is the fulcrum of a long lever *ef*, from which at *d* there is a projection resting on the top of the valve. The end, *f*, of the lever is held down against the steam-pressure by the spring *h*. The pull exerted by this spring can be adjusted by a nut at *f*, and it is fitted with a brass case, and an index so arranged as always to point to a figure which indicates at what pressure per square inch

the steam in the boiler will be able to lift the valve. For most stationary boilers, a weight which can be moved along the lever to any desired position is used instead of the spring.

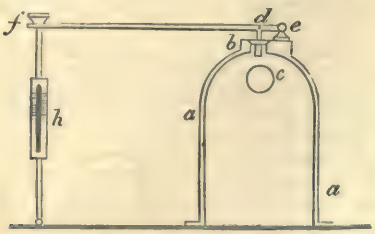


Fig. 4.

In marine boilers, the lever is frequently dispensed with altogether, and weights act directly on the valve. It is also usual, and in steamers compulsory by law, to put two safety-valves on each boiler, one adjustable at will by the engineer, and the other (called the 'government valve') inclosed in a case to which access can only be obtained by means of a key in the possession of the captain. The danger of explosion through overloading the valves is thus obviated.

Although the safety-valve regulates the maximum extent to which the pressure in the boiler can go, it does not indicate its amount or degree. For this purpose, a 'steam-gauge' is used. This generally consists of a small metallic tube (having an elliptical cross section), curved in the form of the letter C, one end of which is fixed, and the other connected by wheelwork or links to an index like a clock-hand. Steam is allowed entrance to the tube at the fixed end, and the higher its pressure, the more the tube tends to straighten itself. The exact amount of this tendency for the different pressures is ascertained, and the dial-plate graduated accordingly. The whole gauge is inclosed in a cylindrical brass box with a glass front.

As serious consequences may result from the water becoming too low in the boiler, and much inconvenience from its being too high, it is necessary always to know its exact level. This is ascertained by two methods—namely, by gauge-cocks, and by a water-gauge. The former are three cocks communicating with the boiler, one just at the right water-level, and the others respectively at the highest and lowest levels that can be safely used. By opening these cocks, therefore, the engine-driver can see (according as steam or water is blown out) the water-level, within certain limits. The water-gauge, however, tells its own tale without compelling any action on the part of the driver. It is shewn in fig. 5, where *aa* is part of the front of the boiler, and *bb* the level of the water. A pipe, *d*, communicates with the steam-space of the boiler, and another, *e*, with the water-space; these are connected by a glass tube *c*, and stop-cocks, *g* and *f*, are so placed as to cut off the connection in the event of the tube breaking. When both cocks are open, the level of the water in *c* is obviously the same as that at *bb*, so that the engineer can see at a glance how the water in his boiler stands.

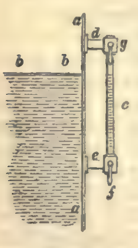


Fig. 5.

Many contrivances have been devised to insure that the boiler shall always have a sufficient supply of water. Some of these are of the nature of a 'self-acting feed,' but the greater part are simply alarums or whistles, so arranged as to make a great noise, which the most careless attendant cannot help hearing, directly the water-level descends below a certain point.

Patents have been repeatedly taken out for inventions intended to do away with hand-firing, so that the stoker should have nothing to do but to fill a hopper in front of the boiler, while the actual feeding of the furnace was done by machinery. Some of these inventions have been successful to a certain extent, both in saving fuel and in preventing smoke; but their expense, complication, and liability to get out of order, have hitherto prevented their coming into extended use.

The steam-pressures used in boilers vary very much. In common factory boilers, the working-pressure is from 30 to 50 lbs. per square inch; in non-compound marine engines, 25 to 35 lbs.; in compound engines, 60 to 80 lbs.; and in locomotives and traction-engines, 100 to 150 lbs.* In order to prevent waste of heat by radiation, all boilers should be covered with some non-conducting substance. Bricks are often used for this purpose, and felt; and there are various compositions which can be laid on like mortar, and harden in their place. The saving in fuel from covering boilers exposed to the air is very great, often as much as 20 per cent.

In some cases the steam, after leaving the boiler, is heated to a temperature higher than that corresponding to its pressure; it is then called 'superheated' steam, and the heating apparatus a 'superheater.' Superheating increases the efficiency of the steam, and, when used moderately, has no bad results; but the steam, when too 'dry,' is found to injure the working surfaces in the valve-chests and cylinders. In almost all marine engines, the steam is slightly superheated.

Having now endeavoured to explain the theory of the action of the steam-engine, and the nature of the apparatus employed for the production of steam, we pass on to consider the engine itself; and before entering on practical details, we think it well to give a few historical notes shewing the rise and progress of the invention.

It appears that the first historical mention of the action of steam for producing motion (though not then proposed to be applied to practical purposes) was in the *Pneumatics* of Hero of Alexandria, in 130 B.C. His instrument was denominated an *æolipyle* (fig. 6), and it may be considered the original form of the steam-engine. The æolipyle consists of a globular metallic vessel, A, which rests on pivots, on which it can revolve with perfect facility. Two tubes, E, E, closed at their extremities, proceed from the ball at right angles to the pivots, and each has a small aperture at F, near its end, through which the steam can escape. The pivots are the extremities of

* These pressures are all expressed in pounds above the atmospheric pressure.

tubes, B, C, connected with the boiler, D, below. On the boiler being heated, steam passes through the pivot tubes into the cylinder, from which it escapes by the holes, F, in the tubes, E, E. In escaping, it rushes out with great force, and by its reaction on the sides of the tubes opposite the holes, it forces them and the cylinder to revolve in a contrary direction.

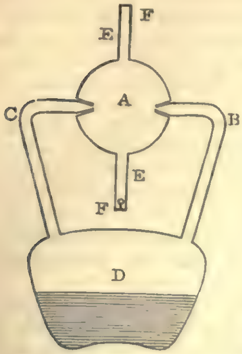


Fig. 6.

In 1543, a Spaniard, Blasco de Garay, is said to have propelled a boat in Barcelona harbour by the power evolved from a caldron of boiling water; and in the beginning of the 17th century, various attempts seem to have been made to make use of steam. The only notice of steam-power at this time, however, which is interesting to us, occurs later on in the century. In 1663, the Marquis of Worcester, during his confinement in the Tower, wrote his famous book, *A Century of the Names and Scantlings of such Inventions as at present I can call to mind to have tried and perfected.* Under the name of 'Fire-waterwork,' he describes a machine for raising water by means of steam, which appears to have been actually at work at Vauxhall in 1656.

In 1698, Captain Savery obtained a patent for a steam-engine, which was the first used to any extent in doing work, most earlier engines having been little better than scientific toys. His engines seem to have been employed for some years in the drainage of mines in Cornwall and Devonshire. The essential improvement in them over the older ones was the use of a boiler separate from the vessel in which the steam did its work. One vessel, in all former engines, had served both purposes.

In all the attempts at pumping-engines hitherto made, including Savery's, the steam acted directly upon the water to be moved without any intervening part. To Dr Papin, a celebrated Frenchman, is due the idea of the *piston.* It was first used by him in a model constructed in 1690, where the cylinder was still made to do duty also as a boiler; but in an improved steam-pump invented about 1700 he used it as a diaphragm floating on the top of the water in a separate vessel, or cylinder, and the steam, by pressing on the top of it, forced the water out of the cylinder at the other end.

The next great step in advance was made about 1705 in the 'atmospheric' engine, conjointly invented by Newcomen, Cawley, and Savery. This machine held its own for nearly seventy years, and was very largely applied to mines, so that it will be worth while to give a somewhat more detailed description of it than of the others.

In this engine, which is shewn in fig. 7, the previous inventions of the separate boiler, and of the cylinder with its movable steam-tight piston, are utilised, although in a new form. The 'beam,' which has ever since been used in pumping-engines, was used for the first time, and for the first time also the condensation of the steam was made an instantaneous process, instead of a slow and gradual one. The boiler, B, is placed over a furnace; from it a pipe conveys the steam to the cylinder, C, immediately connected with the boiler,

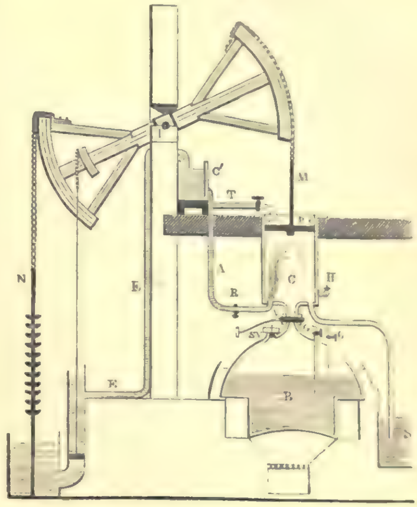


Fig. 7.

the supply of steam being regulated by the valve, V. The level of the water in the boiler is ascertained by the gauge-cocks, G, G, and the pressure of the steam by the safety-valve, SV. The piston, P, works in the cylinder, C, and is kept tight by a stream of water issuing through a pipe regulated by a stop-cock, T, and supplied from a cistern, C′. From the same cistern, the water for condensing is supplied to the cylinder by the pipe, A; the water of condensation is led from the interior of the cylinder by a pipe to a cistern, S, this being placed at a considerable distance below the cylinder, in order to balance the atmospheric pressure, which would otherwise force the water up the pipe into the vacuum created in the cylinder. The air which gains access to the cylinder with the steam is allowed to pass off through the snifting-valve, H, which opens upwards. The piston-rod, M, is connected by a chain to a quadrant placed at the end of a beam, which vibrates on a centre, I; the pump-rod, N, is attached in a similar manner to the other end of the beam. A second and smaller pump supplies the cistern, C′, through the pipe, EE. The operation of the engine is as follows: The fire being properly raised, and steam freely formed, the valve, V, is opened, to allow the entrance of the steam into the cylinder. Although the pressure of the steam is at most not more than that of the atmosphere, the pump-rod, N, with its counterweights, is so much heavier than the piston-rod, that it at once falls, and consequently raises the end, M, preparatory to another stroke. The regulator-valve, V, is now shut, and the stop-cock, R, on the pipe, A, being opened, the cold water is injected, and condenses the steam. But as a vacuum is made by the condensation of the steam, the pressure of the air, acting with a force equal to nearly 15 lbs. per square inch on the surface of the piston, carries it down to the bottom of the

cylinder, and consequently raises the other end of the beam, to which the pump-rod, N, is attached. In this manner, the water is raised from the mine, and by a repetition of the movements already noticed, a constant discharge of water results.

It will be noticed that the work in this engine is not done by the pressure of the steam, but by the pressure of the atmosphere on the upper side of the piston, when the steam in the cylinder is reduced by condensation to a very small density. Hence arises its name of 'atmospheric' engine.

At the beginning of the 18th century, a boy named Humphrey Potter (to save, it is said, the trouble of personal superintendence) devised a system of strings and levers, by which the engine was made to work its own valves. In 1717, Henry Beighton, an F.R.S., invented a simpler and more scientific system of 'hand-gear,' which rendered the engine completely self-acting. During the latter part of the time that elapsed before Watt's discoveries changed everything, Smeaton brought Newcomen's engine to a very high degree of perfection. As the result of study and experiment, he made many improvements in it, in the form of the boiler, the proportions of the cylinder, &c. It was he, too, who invented the *cataract*, a very ingenious self-acting valve arrangement, which is still universally used in Cornish engines. It is worth mentioning that, in 1725, Leupold invented an engine in which steam of a higher pressure than that of the atmosphere was employed in the cylinder, but his engine possessed defects that prevented it ever being practically used.

Great as was the advance of the steam-engine between 1700 and 1770, its defects were still most serious, the chief among them being its enormous waste of heat. Much steam was lost in reheating the cylinder after each condensation, for it had always at least to be raised to the temperature of the steam before the steam could, as such, continue in it, and be in any degree efficient; and on the other hand, the cold air which followed the descent of the piston necessarily withdrew a considerable portion of heat. By the calculations of Watt, it was estimated that *three* times as much steam was expended in this manner as would have been equal to work the engine—a loss, therefore, equal to 75 per cent. Nevertheless, this, as has been correctly observed, 'was the first really efficient steam-engine—that is, the first engine which could be applied *profitably* and *safely* to the most important purposes for which such machines were required at the time of its invention.'

The great philosopher and inventor, James Watt, to whom we really owe the steam-engine in its present form, was, as is well known, a mathematical instrument-maker in Glasgow. He appears to have made experiments on the properties of steam about 1761, but it was not till three years afterwards that he took the steam-engine up in earnest. In 1764, he had to repair, in the course of his business, a model of an atmospheric engine belonging to the university of Glasgow. It was a very small machine, with a cylinder 2 inches diameter, and 6 inches stroke. Its defects, however, led him to study its principles (a thing which no one had really done before him), and in the course of a few years he had given to the world the wonderful series of inventions which practically made the steam-engine what it is still, all subsequent improvements having been comparatively matters of detail.

Former inventors and improvers had worked at the steam-engine empirically; Watt went into the whole matter scientifically. He studied the properties of heat, and the laws of elastic fluids, as far as they were known in his time, and the relations between the temperature, volume, and pressure of steam. In the specification of his patent of 1769 he embodied the principles which his studies had led him to recognise in the following memorable clauses:

'My method of lessening the consumption of steam, and consequently fuel, in fire-engines, consists of the following principles:

'First, That vessel in which the powers of steam are to be employed to work the engine, which is called the cylinder in common fire-engines, and which I call the steam-vessel, must, during the whole time the engine is at work, be kept as hot as the steam which enters it; first, by inclosing it in a case of wood, or any other materials that transmit heat slowly; secondly, by surrounding it with steam or other heated bodies; and thirdly, by suffering neither water nor any other substance colder than the steam to enter or touch it during that time.

'Secondly, In engines that are to be worked wholly or partially by condensation of steam, the steam is to be condensed in vessels distinct from the steam-vessels or cylinders, although occasionally communicating with them; these vessels I call condensers; and whilst the engines are working, these condensers ought at least to be kept as cold as the air in the neighbourhood of the engines, by application of water, or other cold bodies.

'Thirdly, Whatever air or other elastic vapour is not condensed by the cold of the condenser, and may impede the working of the engine, is to be drawn out of the steam-vessels or condensers by means of pumps, wrought by the engines themselves, or otherwise.

'Fourthly, I intend, in many cases, to employ the expansive force of steam to press on the pistons, or whatever may be used instead of them, in the same manner in which the pressure of the atmosphere is now employed in common fire-engines. In cases where cold water cannot be had in plenty, the engines may be wrought by this force of steam only, by discharging the steam into the air after it has done its office.

'Lastly, Instead of using water to render the pistons and other parts of the engines air and steam tight, I employ oils, wax, resinous bodies, fat of animals, quicksilver, and other metals in their fluid state.'

Watt's principal inventions were—1*st*, The condensation of steam in a vessel separate from the cylinder, so as to avoid the cooling of the latter; 2*d*, The use of a pump, called an 'air-pump,' to withdraw the condensed water, and mixed steam and air, from the condenser; 3*d*, To surround the cylinder either with a steam-jacket, or with some non-conducting body, in order to prevent radiation of heat (these three, with others, were included in the specification of 1769); 4*th*, To use the steam expansively in the way explained in a former part of this article (this was invented before 1769, but not published till 1782); and 5*th*, The now universally used double-acting engine, and the conversion of the reciprocating

motion of the beam into a rotary motion by means of a crank (both these were invented before 1778, the engine being patented in 1782, but the crank having before that date been pirated and patented by another). In 1784, Watt also patented and published his parallel motion, throttle-valve, governor, and indicator; all four of which are in substance still used. The principal improvements since the time of Watt have been either in matters relating to the boiler; in details of construction consequent on our increased facilities, improved machinery, and greater knowledge of the strength of materials; in the enlarged application of his principle of expansive working; or in the application of the steam-engine to the propulsion of carriages and vessels.

We have said that Watt invented the 'double-acting' engine. By this we mean such an engine as was sketched in fig. 1, in which the steam acts on both sides of the piston, instead of only on one, as in Newcomen's engine. Watt's engine, although not of the form now generally used, contains all the parts now considered essential; and before describing these parts in detail, we will therefore describe it as it is illustrated in fig. 8. The steam from the boiler passes direct to the valve-chest, *v*, which is simply a long box attached to the cylinder, *a*. In this chest are placed valves, which are so regulated as to open communication between the boiler, cylinder, and condenser, in such a way that when the top of the cylinder is open to the boiler, the bottom communicates with the condenser, and *vice versâ*. When the steam has done its work, it passes out through the bent pipe into the condenser, *f*, where it is met by a jet of water (not shewn in the engraving), and condensed, as before explained. *g* is a pump called the air-pump, which continually draws away the contents of the condenser, and discharges them into a cistern, *h*, called the hot well. A small force-pump, *j*, draws part of the water from this cistern, and sends it back again to the boiler, there to be reconverted into steam, while the rest of the water is allowed to run to waste. A suction-pump, *k*, supplies water to the large tank round the condenser, and also for the condensing jet. Inside the cylinder are the piston and the rod (called the piston-rod) connecting it with the beam, *bb*. In Newcomen's engine, the rod had only to pull the beam down, and not to push it up; it could, therefore, be connected to it by a chain, as shewn in fig. 7. In the double-acting engine, the piston-rod is required both to pull and to push the beam, so that the chain is no longer admissible. It is obvious that as the head of the rod must move in a straight line, while every point in the beam describes an arc of a circle, the two cannot be rigidly connected. Watt invented the arrangement of rods shewn in fig. 8, by which the piston-rod head is always guided in a straight line, while the end of the beam is left free to pursue its own course. This is called a 'parallel motion.' The end of the beam furthest from the cylinder is connected by a rod, *cc*, called a connecting-rod, to the crank, *l*, which is firmly fixed on the shaft; and by this means the reciprocating motion of the beam is converted into the rotary motion of the 'crank-shaft,' *r*. The governor, *m*, and the fly-wheel, *ee*, will be explained further on.

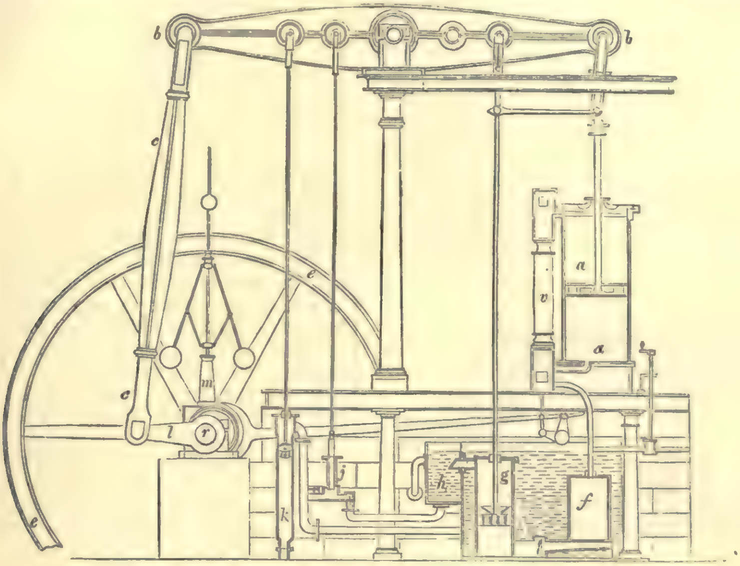


Fig. 8.

Having now given a general idea of the progress of the steam-engine up to the time of Watt, and of its construction and arrangement, we devote the remainder of our space to a detailed description of the construction and uses of its various parts, as they are made in modern engines, and to a glance at the principal modifications of Watt's engine which are now in use.

The principal materials used in the construction of steam-engines are cast-iron, malleable or wrought iron, and brass. Steel and copper are also used to a small extent. All parts of complex form, such as the cylinder, bedplate, &c. are made of cast-iron. The moving parts, such as the piston and connecting rods, shaft, valve-gear,

&c. or any pieces subjected to tensile strain, and all bolts, nuts, and other fastenings, are made of wrought-iron, forged in the smithy into the desired shape, and afterwards finished in the machine-shop. Brass or gun-metal is used generally for parts working under water, as well as for most of the wearing surfaces about the engine. Steel is sometimes used for rods and bolts, when great strength has to be combined with lightness. Copper is used largely for the pipes where lightness is any object, but cast-iron is the common material in other cases.

The Cylinder.—This is always made of cast-iron, and is generally covered outside with non-conducting material, to prevent radiation of heat, and often inclosed in a *jacket* supplied with steam from the boiler, in order to prevent loss from several causes—principally from internal condensation. In fig. 9, AA is the cylinder, and B the jacket. The piston-rod, E, is made to work through a 'stuffing-box,' F, in order to prevent the leakage of steam. C and D shew the *ports*, or openings for the entrance and discharge of the steam. They lead from the cylinder into a valve-chest or box in which the valves (to be afterwards described) work.

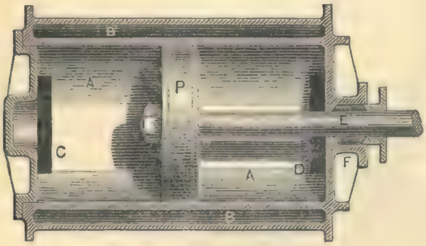


Fig. 9.

The Piston (P, fig. 9) is also made of cast-iron. It is obviously necessary that its circumference should fit exactly the bore of the cylinder, even after long working, and it is made to do so by means of springs or other contrivances.

The Valve or valves that regulate the admission of steam to the cylinder are very various in construction and design. Sometimes they are four in number, each end of the cylinder having both an induction and an eduction valve. Sometimes two valves are used; but in ordinary modern engines, one valve (called a slide-valve) is made to do the whole work for each cylinder, in a way which we will explain by the aid of fig. 10. This figure shews the valve in two positions—namely, those corresponding to the times when the piston is at the middle of its stroke, going in the two different directions—*c* and *d* are the ports, the ends of which are denoted by the same letters in fig. 1; *b* is the 'exhaust port,' or opening through which the steam passes to the condenser; and *a* is the slide-valve working inside the steam-chest (not shewn). The sketch to the left shews the position of the valve when the piston is moving upwards. The steam enters the cylinder through *d*, as shewn by the arrows, while the steam in the other end is free to rush out by *c*, under the valve, and through *b* into the condenser. By the time the piston has reached the same position, going in the opposite direction, the valve is in the position shewn in the right-hand sketch, and the motion of the steam is exactly reversed.

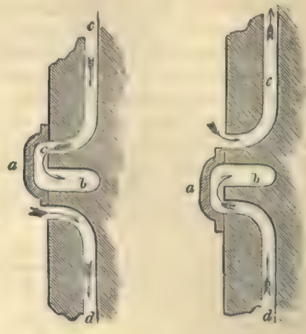


Fig. 10.

By the very simple expedient of lengthening the ends of the valve, the engine can be worked expansively. The amount by which each end is longer than the width of the port is called the *lap* of the valve; and the greater the amount of the lap, the earlier in the stroke is the steam cut off. We have not space to explain the reason of this, but it will be found fully gone into in most of the popular treatises on the steam-engine. Various practical considerations make it unadvisable to cut off the steam much before half-stroke by means of lap, and therefore, when it is desired to expand the steam into more than twice its original volume, a separate valve is employed, called an *expansion valve.* Numberless varieties of these valves are used, some working on the back of the slide-valve, and some in a separate chamber; the principle of them all is that they merely affect the entrance of steam into the cylinder, while its exit is controlled by the slide-valve. Expansion valves are generally so arranged that the engineer can alter the degree of expansion at will, by moving a wheel or lever.

It will be seen that if the valve only commenced to open the port at the same instant that the piston was ready to commence its stroke, the engine could not work, unless the momentum of the moving parts was sufficient to keep the shaft in motion, and so carry the piston on, until the valve was sufficiently open to admit the steam. Although this would generally be the case, yet it is of great importance that the admission of steam should be as prompt and quick as possible; and with this object engineers always allow the valve what is called *lead.* This simply means that the slide-valve is allowed to have opened the port about one-eighth of an inch before the piston has really arrived at the end of its stroke.

The valves are almost invariably worked by *eccentrics*, through the intervention of suitable rods and levers called the *valve-gear.* An eccentric is an ingenious substitute for a crank. It consists essentially of a circular disc of metal with a hole in it. The centres of the disc and hole do not coincide, and hence its name of *eccentric.* The shaft of the engine passes through the hole, and the shaft and eccentric are so fixed together that the latter must revolve with the former. A ring called a 'strap' is placed round the eccentric, and connected by a rod to the spindle of the valve.

The strap receives from the eccentric a circular motion exactly similar to that given by the connecting-rod to the crank pin, and this motion the rod transforms into a reciprocating one, and transmits to the valve. The process is exactly the reverse of that by which the reciprocating motion of the piston-rod is changed into a circular one, and transmitted to the crank by the connecting-rod. The varieties of valve-gear and expansion-gear are as endless as the varieties of valves. Many of them are highly ingenious, and many absurdly complicated, while not a few possess both these qualifications. Any detailed description of them, however, is unnecessary here.

The Fly-wheel is a large wheel fixed on the crank-shaft, and having a very heavy rim. Its use is to equalise the motion of the shaft, and to enable, by its momentum, the engine to pass what are called the 'dead points'—these will be found described in the article MECHANICS.

The Condenser is simply a cast-iron box of any convenient shape. The water for condensing the steam is introduced into it in a jet in such a way that its particles mix with the steam at once on entering, and condense it almost instantaneously. The 'surface condenser,' in which the steam is condensed by contact with the surface of a number of small tubes, through which a current of cold water continually flows, is one of the most important of modern improvements, and will be found described further on. It is, however, only of use when the injection-water contains unvaporisable matter—such as the salt in sea-water—which would otherwise be deposited in the boiler as a crust, and do much harm.

The Governor, shewn in fig. 11, is an ingenious application by Watt of mechanism long used in water-mills. Its object is to make the engine to a great extent regulate its own speed, so that it shall neither be pulled up altogether by a sudden increase of load, nor 'race' when any part of its load is suddenly removed. It consists essentially of a spindle or upright rod, with a pulley, by which

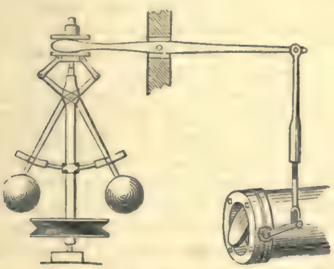


Fig. 11.

it is caused to revolve, fixed on it. Two bent levers are pivoted on a pin near the top of the spindle, and at the lower end of each is fixed a heavy cast-iron ball. When the engine is running at its proper speed, the balls revolve with the spindle in the position shewn; but if that speed be increased, the centrifugal force causes them to fly outward, and consequently upward; and conversely, if it be decreased, they fall downward towards the centre. At the upper end of the spindle is a system of levers, by which it will be seen that the raising of the balls tends to close, and their lowering to open, the *throttle-valve* at the right of the engraving. This valve is simply a disc of metal placed in the steam-pipe near the cylinder. The further, therefore, it is opened, the greater the amount of steam admitted to the cylinder, and *vice versâ*, and so the tendency of the engine to alter its speed arising from causes extraneous to itself, is just balanced by the alteration made in the amount of steam admitted through the throttle-valve.

In all marine and locomotive engines, as well as in many stationary ones, it is essential that the crank-shaft should be able to revolve in both directions, and for this purpose they are fitted with *reversing-gear*. The direction in which the shaft of an engine revolves depends entirely on the position of the eccentric which works the valves in relation to the crank. The reversing-gear which is now almost universally used is called the 'link-motion,' and its construction is shewn in fig. 12. In it two eccentrics are used,

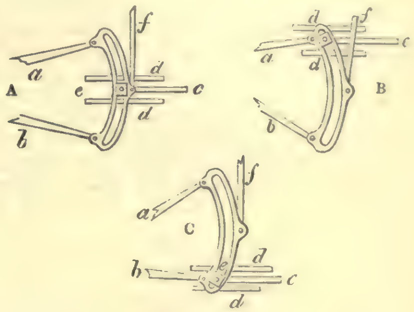


Fig. 12.

called 'forward' and 'backward,' according to the direction in which their action on the valve causes the shaft to turn. *a* is the rod of the forward eccentric, and *b* the rod of the backward eccentric. These are respectively jointed to pins at the top and bottom ends of a curved link, in the centre of which is a slot or opening. The valve-rod *c* has a cross-head which slides between two parallel faces, *d*, *d*, and is thus compelled to move in a straight line. It has also a small block, *e*, at its extremity, which fits the slot of the link. By means of a rod, *f*, the link can be lifted or lowered, and the position of the block of the valve-rod in the slot can thus be altered. Thus the link may be raised so as to make the block occupy the lowest part of the slot, as at C, or it may be lowered so as to make it occupy the highest part, as at B. A shews a position midway between the other two. When the link occupies the position B, the valve-rod receives the full motion of the forward eccentric, and in consequence, the engine turns in its usual direction. When, however, its position is altered to C, the valve-rod receives the full motion of the backward eccentric, and the engine consequently moves in the reverse direction. If the link is placed in any intermediate position, the valve obviously receives only a part of the full stroke of the eccentric. This (which is called 'linking-up') has been found to be equivalent to increasing the lap, and the link-motion thus serves (up to a certain point) the purpose of a variable expansion-gear.

We must now proceed to describe the principal varieties of steam-engines at present in use. Of these, the one most resembling Watt's engine is called the 'Cornish' engine, from the fact that it is principally used in the Cornish mines. It is used as a pumping-engine exclusively, like Newcomen's, and has no rotary motion. Unlike his, however, the steam, and not the atmospheric pressure, is made to do the work. It has a vertical cylinder connected with a beam, like that in Watt's engine; but the other end of the beam is simply attached direct to the upper end of the pump-rod which descends the shaft. It has a condenser and air-pump like Watt's double-acting engine. Its mode of action is as follows: When the pump-plunger is at the bottom of its stroke, ready for a lift, the piston is at the top of the cylinder. Steam is admitted above the piston of a pressure very much higher than that required to raise the weight of the water and pump-rod. This sets the beam in motion, lifting the water, pump-rods, &c. The steam is very soon 'cut off,' and allowed to expand, and the pressure in the cylinder therefore falls rapidly, as before explained. Some time before the stroke is finished, the force acting on the piston has come to be *less* than the resistance at the other end of the beam, but the momentum acquired by the latter is sufficient to keep it from stopping suddenly; and the steam-pressure and momentum are so arranged that the piston is brought gradually to rest just before it touches the bottom of the cylinder. The work of the stroke has now been done, and valves are opened which establish free communication between the two ends of the cylinder. The steam being thus able to flow from the upper to the under side of the piston, and offering no resistance to its motion, the weights at the pump end of the beam pull it up to the top of the cylinder again, ready for another stroke. A small volume of steam is always left above the piston to act as a cushion, and prevent the piston striking the cylinder cover. During the descent of the piston, the space beneath it is opened to the condenser in the usual way.

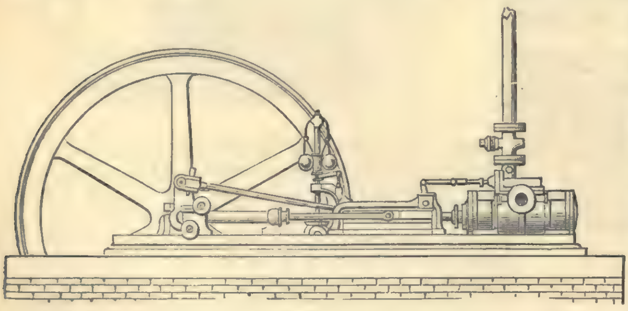


Fig. 13.

It is difficult to say why Cornish engines have remained so long in their original form. They are economical of fuel, owing to the great expansion used, but the same expansion could be used with many other forms of engine. They are very costly, and extremely heavy and unwieldy, and it seems probable that it is only prejudice which stands in the way of the substitution for them of small engines running at very high speeds, which would do the same work with a very much smaller first cost.

In all the engines we have hitherto mentioned, there has been some part or parts intermediate between the piston-rod and the connecting-rod. In modern engines, however, there is more and more a tendency to discard such intermediate parts, and to make the engine 'direct-acting.' The commonest type of direct-acting engine is the Horizontal, shewn in fig. 13. For all ordinary purposes, this type of engine is rapidly superseding every other form of stationary engine. It possesses the merits of having great simplicity and few working parts, and of all these parts being easily accessible to the engine-driver; and at the same time any required degree of economical working can be attained as well by it as by any form. It will be seen from the engraving that the cylinder and other fixed parts of the engine are bolted down to a 'bedplate' which extends along its whole length. The connecting-rod is attached direct to the piston-rod-head, and through the latter is fixed a piece called a *cross-head.* The ends of this cross-head are compelled to move in straight lines by working between rigid guide-bars. The other end of the connecting-rod is attached, as before, to the crank-pin. The feed-pump is worked from one end of the cross-head, as shewn in the figure. This form of engine was for a long time only used as a non-condensing, or, as it was then called, high-pressure engine, but it is now frequently made with a condenser. In this case, the bedplate is prolonged behind the cylinder, and on this prolongation a casting is fixed which contains condenser, hot well, and air-pump. The last is horizontal, and worked by a prolongation of the piston-rod through the cylinder cover.

Two other forms of direct-acting engines have been much used in their time, but are now being rapidly abandoned, except under special circumstances. These are called respectively the 'oscillating' and the 'trunk' engine. The former has rarely been used except for marine engines. In it the crank-shaft is above the cylinder, the piston-rod-head is attached to the crank-pin, and the connecting-rod is dispensed with by allowing the cylinder to vibrate or oscillate on large hollow centres, called *trunnions,* and so to adapt itself to the various positions of the crank-pin. The steam passes to and from the cylinder through the hollow trunnions. The principle of the trunk-engine is illustrated in fig. 14. In this engine, instead of shortening the distance between the cylinder and shaft by dispensing with the connecting-rod, the same object is attained by omitting the piston-rod. In the figure, *aa* is the cylinder, *b* the piston, and *cc* a hollow cylinder or trunk attached to it, and taking the place of the piston-rod. The connecting-rod, *d*, is attached to the piston at one end, and to the crank-pin at the other, the trunk, *c*, being of sufficient diameter to allow for its vibration. This form of engine, like the oscillating, was chiefly used in marine work.

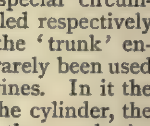


Fig. 14.

Before speaking of locomotive and marine engines, we may just mention another class not yet alluded to, entirely different in arrangement from those already described. We refer to the class called *rotary* engines. In these machines we still have a piston and cylinder, although different in construction from the parts bearing those names in ordinary engines; but the piston- and connecting-rods, crank, fly-wheel, &c. are all dispensed with. The main shaft runs right through the centre of the cylinder, and the pistons (there are generally more than one) form wings, filling up the distance between the shaft and the circumference of the cylinder. Steam, when admitted into the cylinder, imparts either a rotary or vibrating motion to the pistons, in such a way that a continuous revolving motion is given to the shaft. An immense amount of ingenuity has been expended on these engines, and the patents taken out for them are innumerable. This has arisen to a great extent from the erroneous idea that in the reciprocating motion, and the consequent 'dead points,' much power is lost. We have not room here to shew why this is not the case; the argument will be found at length in most modern works on the steam-engine. The friction and liability to wear in almost all rotary engines hitherto constructed, as well as the difficulty of working them expansively, has prevented their coming into use except on a very small scale.

In locomotive engines, it is necessary that the whole machinery should be compressed into the smallest possible bulk, and this necessity is the cause of their principal peculiarities. The engine itself is much the same as an ordinary horizontal engine; it has two cylinders side by side placed near the front of the engine, and the piston and connecting-rods are arranged exactly as described in fig. 13. The cylinders are sometimes placed inside the main framing, which runs the whole length of the engine, and sometimes outside it, each plan having certain advantages. Locomotive engines are always non-condensing, because of the impossibility of their carrying the amount of water that would be required for condensing, as well as the great additional dead-weight which a condenser with its necessary pumps, &c. would add.* The leading feature of a locomotive is its boiler, which we will now proceed to describe by the aid of fig. 15, which is a section of an

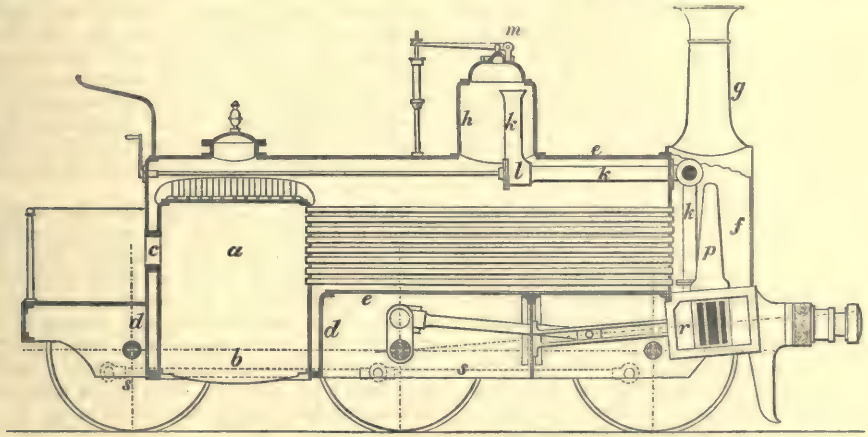


Fig. 15.

'inside cylinder' goods locomotive belonging to the Midland Railway Company.

At the back of the engine (the end nearest the foot-plate) is the fire-box *a*, a rectangular box, the bottom of which is formed by the grate *b*. Fuel is introduced by the door *c*. The fire-box is inclosed in a casing *d*, and the space between them, forming part of the boiler, is constantly filled with water. This water-space communicates with the barrel of the boiler, *e*, which is simply a long wrought-iron cylinder, made perfectly steam-tight. From the back of the fire-box, numerous small tubes traverse the boiler (through the water), and convey the heated air and gases from the furnace to the smoke-box, *f*, which is an iron box at the front of the barrel, forming the base of the funnel *g*. In this particular engine there are about 170 tubes, each 2 inches diameter, and over 11 feet long, presenting to the water altogether a heating surface of almost 1000 square feet. To obtain this enormous surface, which is needful for the proper working of the engine, is the reason why this form of boiler is used. On the centre of the barrel is a dome, *h*, and from near the top of this dome the steam-pipe, *k*, is led away. By this means the steam is obtained less mixed with spray than it would have been had it been taken only from the top of the barrel. *l* is the regulator, which, by means of a handle worked by the driver, governs the amount of steam allowed to go to the cylinders. On the top of the dome are two spring safety-valves, *m*, placed side by side. The engine is fitted with reversing-gear worked by a lever on the foot-plate, but the small scale of the engraving does not permit these to be shewn. The cylinders discharge their steam through pipes which meet in the centre of the engine, in the vertical blast-pipe, *p*. It is, of

* On the Metropolitan (Underground) Railway the steam is condensed for short periods at a time by discharging it into a tank, but it is obvious that such a plan is only applicable to a very limited extent, as the water would soon get heated so much as to prevent useful condensation. The object in this case, too, is not so much to get rid of back-pressure, as to avoid discharging steam in the tunnels.

course, impossible in a locomotive to induce a draught through the furnace by means of a tall chimney, as is done in stationary and marine engines. By the device of the blast-pipe, however, this difficulty is obviated, as the exhaust steam, rushing up the chimney, causes a sufficient flow of air through the furnace. The cylinders, *r*, are placed at the bottom of the smoke-box, and partly inclosed in it. In this engine, in order to secure greater adhesion on the rails, the whole of the six wheels are coupled together by connecting-rods, as shewn at *s*, *s*. The engine is always attended by a tender, in which the fuel and water are conveyed.

A few notes on the history of steam locomotion may not be amiss in this place. The first practical locomotive for working on a line of rails (see INLAND CONVEYANCE) was that patented by Richard Trevithick in 1804. It ran on a colliery railway at Merthyr-Tydvil in Wales. Many of the arrangements and appliances of the modern locomotive are to be met with in this its earliest form. One of the principal features of the locomotive of the present day—the blast-pipe by which the waste steam increases the draught—was used in this engine.

It was, however, to the genius of the celebrated George Stephenson that the modern locomotive owed its existence. Others lent important aid in perfecting the mechanical details; but without the admirable inventions of Stephenson in connection with railways, the locomotive could never have arrived at its present efficiency. 'That the modern locomotive,' says Mr Scott Russell, 'could not subsist without the wrought-iron rail, and its multifarious appendages of chains, keys, locks, sleepers, switches, crossings, sidings, and turn-tables, is too evident to need proof. Without the smoothness of the rail, the engine would be jolted to pieces; and without the easy motion which it gives, the engine could not be made to draw a sufficiently profitable load to pay; and further, unless made of wrought-iron, it would be impossible to attain the high speed of the locomotive without imminent danger. It therefore appears that the continuous wrought-iron railway and the locomotive engine were inventions intimately related to each other, and each a condition of each other's success. To Stephenson we are indebted for the chief features of both.'

In 1814, being pecuniarily assisted by Lord Ravensworth of Killingworth Colliery, he constructed a locomotive which was tried on a tramway there. This was subsequently improved, and tried at other places; but the mechanism of the engines was not sufficiently well arranged to render them economical and efficient, and in spite of his exertions Stephenson failed to bring them into use. The opening of the Manchester and Liverpool Railway gave him an opportunity of bringing out an efficient locomotive, worthy of the new field of its operations. The result was the awarding of the prize of £500 for the best locomotive to the *Rocket*, the engine entered by Stephenson. This engine, which, with its own weight alone, traversed the railway at a speed of twenty-nine miles an hour, created an interest in the new power which has never since then ceased to exist, and which, by directing to it the attention of such able mechanicians as Hackworth, Hawthorn, Fairbairn, and many others, resulted in establishing that wonder of modern times—railway travelling. The *Rocket*, after doing many years' work, is now placed as an historical monument on a pedestal outside Darlington Station.

More or less akin to locomotive engines in their general appearance and arrangement are portable and traction engines. The former may be described (with some self-contradiction) as locomotives that cannot propel themselves. They consist of a locomotive boiler set on wheels, with a small horizontal engine bolted on the top of it. They are used mostly by farmers for working agricultural machinery, and the wheels are to enable them to be drawn by horses from place to place about the farm.

Traction engines are locomotives adapted to run on common roads instead of on rails. The greatest invention of recent date in connection with them is Mr Thomson's 'Road-steamer,' the essential feature of which is, that the wheels are surrounded with thick rings of india-rubber, forming their tires. This gives great adhesion with a very light engine, and at the same time greatly diminishes the jolting and vibration which has hitherto been the destruction of almost all traction engines. The principal drawback to these engines at present seems to be the very high price of the india-rubber tires; and like all other inventions, they require long trial and experiment before they can be said to be quite perfect. It seems probable, however, that before many years we shall see very much of the work now done by horses executed by steam-power, just as machines have to so large an extent superseded hand-labour in factories.

In the article MARITIME CONVEYANCE will be found a full description of marine engines, so that we need here only mention their leading features. During the time when paddle-wheels were the only means of propulsion used in steam-vessels, there were two leading classes of marine engines, the 'side-lever' and the 'oscillating.' The latter has been already described; the former was for a long time the form which was regarded as the standard, and is illustrated in fig. 16. It is

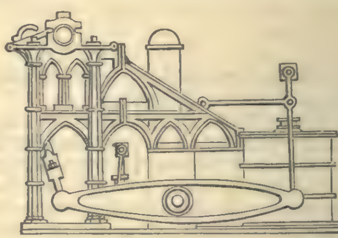


Fig. 16.

a beam-engine, but in order to save height, the beams (for there is one on each side) are placed beside instead of above the cylinder. The piston-rod cross-head is connected by links to one end of the beams, and the connecting-rod is worked by a cross-head from the other ends, the crank-shaft being right over the connecting-rod end of the beams. In all marine engines except the very smallest two cylinders are used, working cranks at right angles to each other, so as to equalise the motion as far as possible, it being impossible to use a fly-wheel for this purpose on

board ship. Many ingenious arrangements of the machinery in paddle-steamers have been devised, notably by Maudslay; but on the whole the oscillating engine held its own until the screw-propeller virtually superseded the paddle-wheel. Oscillating engines with inverted cylinders have been used for working screws, but not successfully, partly because of the high speed at which the propeller shaft must run, and partly because along with the screw high pressures of steam came into use, and there are many practical difficulties in the way of using high-pressure steam in oscillating cylinders.

With the invention of the screw-propeller, everything was speedily changed. For a few years screw-engines continued to be the same ponderous, slowly-moving machines that had been used to work paddle-wheels, and toothed gearing was used between the crank and the screw shafts to increase the speed of the latter. These, however, were soon abandoned, and direct-acting engines took their place. Trunk-engines were often used, and also engines in which each cylinder had two piston-rods passing right across the shaft (one on each side of it), and attached to the connecting-rod at their further ends. This rod thus occupied the side of the vessel opposite to that in which the cylinder was placed; and from its working *back* towards the shaft, this form of engine is called the 'return connecting-rod' type.

In vessels of war, where it is essential that all the machinery should be kept low in the ship, this form of engine is still used. Although more complicated than the trunk-engine, it is more economical, for much heat is lost from the large surface presented to the air by the trunk when it is out of the cylinder, as it must be at every stroke. In merchant-vessels, however, and all cases where there is no necessity for the machinery being kept low down in the ship, the form known as the 'steam-hammer' engine is now almost universally adopted. These engines derive their name from their resemblance (in their earlier forms) to Mr Naismith's steam-hammer, the form of which seems to have suggested their arrangement. They are direct acting, but the cylinders are inverted, and placed right above the shaft.

The two greatest improvements of modern times—namely, the surface-condenser and the compound engine—having been brought to perfection chiefly in connection with marine engines, we may mention them in this place. In sea-going steamers, it is obvious that the only water obtainable in sufficient quantity for condensing purposes is the salt water surrounding the vessel. The air-pump, therefore, will discharge into the hot well a mixture of sea-water and condensed steam, the former largely preponderating. The feed-pump supplies the boiler with water drawn from the hot well, which must therefore be largely impregnated with salt. As the salt is not vaporisable, it will gradually accumulate in the boiler, and form a hard crust on the tubes and furnaces. This crust not only interferes, on account of its bad conducting qualities, with the efficiency of the heating surface; but its accumulation also forms a source of danger, as the iron underneath it is liable to become red hot, and so give way and cause an explosion. To avoid this latter danger, and as far as possible to prevent the formation of 'scale' (as the crust is called), it is necessary frequently to 'blow off' from the boiler a quantity of saturated brine. As this brine has been raised to the full temperature of the steam before it is blown off, it is obvious that the practice, though necessary, wastes an immense quantity of heat. The object of the surface-condenser is to avoid this waste. In it the steam is condensed by contact with the surface of a great number of small tubes, through which a current of cold water is kept constantly flowing. By this means, the condensing water and the condensed steam are kept separate, the former being returned to the sea, while the latter only is sent into the hot well. The boiler therefore is continually fed with distilled water.

In spite of its obvious advantages, the progress of the surface-condenser in public favour has been but slow, partly on account of popular prejudices, partly because of constructive difficulties in the way of carrying out practically what was demonstrably true in theory. The same may be said about the compound engine. These difficulties, however, are now almost entirely surmounted, and compound surface-condensing engines, worked at what would, only a few years ago, have been considered to be dangerously high pressures, bid fair shortly to be universally adopted in steam-vessels where it is desired to attain any considerable degree of economy.

In compound engines, the cylinders are of unequal size—the larger, called the low-pressure cylinder, being from three to four times the capacity of the smaller, or high-pressure cylinder. The steam from the boiler is admitted into the latter in the usual way, and cut off at $\frac{1}{2}$ or $\frac{2}{3}$ stroke; and after doing its work there it is conducted to the large cylinder (where its reduced pressure, by acting on an increased area, does as much work as in the other cylinder), and thence to the condenser. If the large cylinder has four times the capacity of the small one, and the steam is cut off at $\frac{1}{2}$ stroke in the latter, it is obvious that it will be expanded eight times. In cases where a fly-wheel cannot be used, this has many advantages over an engine in which the steam is expanded eight times in a single cylinder. An engraving of a compound marine engine is given in the article MARITIME CONVEYANCE.

The Work done by Steam-engines.—This is estimated in two ways—as *horse-power*, and as *duty*, and the first expression includes two things—nominal, and indicated, horse-power. Thirty-three thousand foot-pounds of work done per minute is called one horse-power, this being considered by Watt as the maximum force which a strong horse could exert. The *nominal* horse-power of an engine has long ceased to be any expression of the actual power it exerts; it is only used as a kind of commercial standard (a very deficient one) for the sale and purchase of engines. It is generally made to depend entirely on the diameter of the cylinder, but the piston area allowed per horse-power is alike in no two of the great manufacturing centres. For horizontal non-condensing engines, about 9 or 10 square inches, and for marine engines, about 24 or 25 square inches of piston area are allowed per nominal horse-power by most engineers in Scotland and the north of England.

The indicated horse-power is the most useful measure we have of the work done by an engine.

It expresses, however, the total work done by the steam on the piston, and does not shew at all what proportion of that work has to be expended in overcoming the friction of the engine itself. It is ascertained by the use of a little machine called an 'indicator,' devised by Watt, and since his time greatly improved, especially by Mr Richards. The indicator consists essentially of a small cylinder, communicating directly with the cylinder of the engine, and fitted with a piston. It is so arranged that this piston is stationary when the pressure in the cylinder is equal to that of the atmosphere, and rises or falls according as the steam-pressure is higher or lower. A pencil connected with the piston is kept in contact with a piece of paper fixed on a vibrating drum, and traces on it a curve, called an indicator diagram or 'card,' from the form of which the engineer can see accurately the pressures at all the different parts of the stroke, and the whole action of the steam in the interior of the engine.

By taking the *mean* pressure per square inch on the piston throughout the stroke (deduced from the indicator card), and multiplying it by the area of the piston, and by the number of feet passed through by it in a minute, we should find the number of foot-pounds of work done by the engine per minute; and this, divided by 33,000, would give the indicated horse-power.

'Duty' is a measure of power used only for pumping-engines, and differs from horse-power in being entirely independent of time. It is the number of foot-pounds of nett work resulting from the consumption of a given quantity of coal, usually either a bushel of 94 lbs. or a hundredweight. At the beginning of this century, the maximum duty that had been attained by any Cornish engine was 20 millions of foot-pounds per cwt. of coal, but six times that duty has since been occasionally obtained. In these engines, it is the actual nett work done which is taken into account; the duty would be 20 or 25 per cent. greater if the total load on the steam-piston had been considered instead.

The duty of a Cornish engine is also the measure of its economy, and a somewhat similar standard is used for portable engines. At the Royal Agricultural Society's annual trials in 1872, a portable engine made by Messrs Clayton and Shuttleworth (having a locomotive boiler, and one cylinder 6 inches diameter by 12 inches stroke) developed a duty equal to almost 79½ million foot-pounds per cwt. of coal. For engines whose power can only be measured by the indicator, the standard of economy is the number of pounds of fuel used per hour per indicated horse-power. In factories where 'dross' is used as fuel, with horizontal engines and Cornish boilers, and where no proper means are taken to insure economy, it is not uncommon to burn from 15 to 20 lbs. of fuel per ind. horse-power per hour; but if the boiler and cylinder are properly covered, and the engine worked expansively, this is reduced to from 8 to 12 lbs. of the same fuel. In marine engines and other cases where the best coal only is used, and where high pressures, surface condensation, and compound cylinders are employed, the consumption of fuel is often as low as 2 lbs. per ind. horse-power per hour.

It is difficult to speak with certainty of the future of the steam-engine. As yet, no signs have arisen of any agent which can be used as a substitute for steam. Gas, air, and air mixed with steam, have all been tried, but hitherto without any such success as to have displaced their rival in the smallest degree, and it seems probable that the steam-engine may hold its own for an indefinite period. It is almost as difficult to form an adequate conception of the advantages already resulting from the use of the steam-engine, as it is to imagine those that are yet to result from its perfection and more extended employment. Navigation, travelling, automatic factory labour, printing, mining, and a hundred other arts, have been brought to their present state by means of this wonderful agent, and have in their turn reacted upon, and improved it. Engineering has now become a science, and improvements can no longer be made empirically. The great mechanicians who have done so much for the present race of engineers—Stephenson, Maudslay, Clement, and many others—did their work completely and thoroughly from their own point of view, and mere mechanical improvements on their work come very gradually. Our increased knowledge of the properties of steam and the laws of heat, as well as of the strength of materials, has given a new direction to recent improvements, which are scientific more than mechanical in substance, and scientific rather than empirical in method. We have had bequeathed to us a machine that will do its work smoothly and without breakages, and in which the mechanical means are well adapted to their respective purposes. Our business is now to make every part proportionate, without either lack of material in one place, or superfluous weight in another; and to apply all our scientific knowledge to obtaining a maximum efficiency from every part of the engine—to make our fuel evaporate as much water as possible, to make our steam do as much work as possible, to let our engine absorb as little power in itself as possible; in fact, to obtain a maximum of economy and simplicity with a minimum of cost. In its adaptation to mills and factories, steam is doubtless more costly than water-power; but being independent of situation or seasons, it is in almost all circumstances preferable. Its steadiness, and the ease with which it can be managed and regulated, are also great recommendations in its favour. As a motive-power in the industrial arts, steam takes the precedence of all others; and viewing it as an economiser of labour and time, it must be assuredly pronounced the greatest of modern mechanical contributors to human progress and comfort.

INLAND CONVEYANCE.

THE artificial conveyance of person and property from one locality to another may be treated under two great heads—*Inland* and *Maritime.* To these, science may in time add a third —namely, *Aërial;* but as yet, all the schemes and experiments in this department have been without much available result. Confining our remarks, therefore, to what is real and practicable—roads, rivers, canals, and railways may be regarded as the main channels of inland transport. The consideration of ocean transport is reserved for a subsequent number. As a fitting introduction to our present subject, both in point of information and interest, we may briefly advert to the modes of conveyance adopted by nations but little advanced in the arts of civilisation.

PRIMITIVE MODES OF CONVEYANCE.

The means adopted in early times for artificial transport were, as may be supposed, of the rudest kind, as is still the case in those countries which are little advanced in the useful arts. The most degrading species of conveyance that seems to have been practised, was the employment of human labour in bearing litters or palanquins, specimens of which, on a scale of barbarous splendour, are now seen in India, Burmah, and China.

The first and most obvious improvement in modes of transport was the substitution of brute for human labour; and it is reasonable to conclude that the value of this practice could not have been long in being pressed on the attention of mankind. We find the term 'beasts of burden' used in the most ancient records, the animals meant being the ass, the horse, and the camel. No trace, however, exists of the progress from *burden* to *draught*, though it also must have taken place at a very early period. The ass and horse are equally adapted for carrying or drawing, but the camel exerts its power only by carrying; draught alone is suitable for the reindeer and ox, the backs of these animals being unfit by nature for burden.

Burden.

From the earliest times, the camel has been employed in the sandy regions of Asia as a beast of burden; and without its invaluable services in this respect, these countries could scarcely have been habitable. The camel is expressly suited by nature for inhabiting and traversing sandy and parched deserts, in which there are places of rest and refreshment only at wide intervals.

The camels, along with the llama, alpaca, &c. of South America, form a family of ruminants called *Camelidæ.* The *Camelidæ* of South America have no trace of the hump or humps that characterise their congeners of the Old World. The hump on the camel's back is a wonderful provision of nature, to adapt the animal to the endurance of long abstinence from food, or subsistence on very scanty supplies, to which it is often subjected in the desert, and without a capacity for which it would be comparatively of little value to man; and the wide deserts, across which he journeys and transports his merchandise by its aid, would be altogether unpassable. The hump is, in fact, a store of fat, from which the animal draws as the wants of its system require; and the Arab is very careful to see that the hump is in good condition before the commencement of a journey. After it has been much exhausted, three or four months of repose and abundant food are necessary to restore it. The back-bone of the camel is as straight as that of other quadrupeds.—Another very interesting adaptation to the desert is to be noticed in the thick sole which protects the feet of the camel from the burning sand, and in callosities of similar use on the chest and on the joints of the legs, upon which the camel rests when it lies down to repose, or kneels, as it does for various purposes, and is taught to do that it may be loaded, or that its rider may mount upon its back. But most interesting of all is the provision made for the camel's endurance of long drought, by the lining of the inside of the second stomach, or honey-comb bag, and of a portion of the first stomach, or paunch, with great masses of cells, in which water is stored up and long retained. This store of water is well known to the Arabs, who, when sore pressed by thirst, sometimes avail themselves of it by killing some of the camels of the caravan.

A caravan sometimes contains 1000, sometimes even 4000 or 5000 camels. The supply of food carried with the caravan for the use of the camels is very scanty: a few beans, dates, carob-pods, or the like, are all that they receive after a long day's march, when there is no herbage on which they may browse. The pace of the loaded camel is steady and uniform, but slow; it proceeds, however, from day to day, accomplishing journeys of hundreds of miles at a rate of about 2½ miles per hour. Some of the slight dromedaries, however, can carry a rider more than 100 miles in a day. The motion of the camel is peculiar, jolting the rider in a manner extremely disagreeable to those who are unaccustomed to it; both the feet on the same side being successively raised, so that one side is thrown forward, and then the other.

Turning to the New World, we find that, from the remotest period to which the Peruvian records extend, the aborigines not only used the llama and alpaca for food and clothing, but also employed them in their military and domestic service, as the Arabs do the camel. The llama was principally destined to carry burdens, although, compared with the Asiatic drudge, the difference in size and strength is considerable. Its load, according to Mr Walton, never exceeded 150 pounds, with which it was not required to travel more than three leagues per day; whereas in the working part of the twenty-four hours the camel journeys double that distance with 800 pounds or more upon his back.

We need scarcely advert to the fact, that wherever civilisation has made any progress, the horse,

the ass, and their hybrid the mule, have been used as beasts of burden—that is to say, in those countries which form their natural habitats. At what period the horse was first subjected to the purposes of man we have no authentic record. He is mentioned by the oldest writers, and it is probable that his domestication was nearly coeval with the earliest state of society. Trimmed and decorated chargers appear on Egyptian monuments more than four thousand years old; and on sculptures equally, if not more ancient, along the banks of the Euphrates. At a later date, Solomon obtained horses 'out of Egypt, and out of all lands,' and had 'four thousand stalls for horses and chariots, and twelve thousand horsemen.' Thus we find that in the plains of the Euphrates, Nile, and Jordan, the horse was early the associate of man, bearing him with rapidity from place to place, and aiding in the carnage and tumult of battle. He does not appear, however, to have been employed in the more useful arts of agriculture and commerce; these supposed drudgeries being imposed on the more patient ox, ass, and camel. Even in refined Greece and Rome he was merely yoked to the war-chariot, placed under the saddle of the soldier, or trained for the race-course. As civilisation spread westward over Europe, the demands upon the strength and endurance of the horse were multiplied, and in time he was called upon to lend his shoulder indiscriminately to the carriage and wagon, to the mill, plough, and other implements of husbandry. It is in this servant-of-all-work capacity that we must now regard him; and certainly a more docile, steady, and willing assistant it is impossible to find. For burden, the ass perhaps is more steady and enduring; but both are surpassed by the mule, which in Spain, South America, Mexico, and other countries destitute of good roads, affords one of the most available modes of commercial transport. Headed by one of superior sagacity, they move in long cavalcades, like the camel and llama, and with their gay caparisons, tinkling bells, and jauntily dressed drivers, form a very picturesque object in the landscape.

Another primitive mode of carriage, and the last which we shall mention, is the employment of the huge and unwieldy but powerful elephant. In the East he had been subjugated and trained before the earliest records. It was to Alexander the Conqueror that the western world was first indebted for the elephant; he it was that made the sports of Persia and India familiar to the Greeks and Macedonians. The acquisition of the war-elephant gave new pomp and splendour to his squadrons, and his example was followed by degrees by other nations. In time, the Egyptians, Carthaginians, and Romans all made use of elephants, both to assist in the march, by carrying enormous loads of baggage, and to join the ranks, mounted by numbers of archers and spearmen, as here represented.

Since the introduction of firearms and artillery, the war-elephant has been greatly abandoned even in the East, and is now chiefly used in carrying baggage, in doing other heavy work, and, above all, in adding to the 'pomp and circumstance' of Oriental authority. The present employment of the elephant in India is exceedingly varied—from the piling of firewood and the drawing of water, to the dragging of artillery and the carriage of royalty. When placed under the *howdah*—a covered seat for persons of rank—his back is protected by a thickly stuffed hair-cushion, over which is spread

an ornamental covering. The howdah is made to contain several persons, and this is the amount of the travelling elephant's burden.

Draught.

The draught of the reindeer is employed in Lapland as the chief means of artificial locomotion, and is always exerted on a species of sledge, which, by its form, is suitable for gliding easily over the frozen ground or snow. The shape of the sledge somewhat resembles a small boat with a sharp prow, and flat in the rear, against which the inmate of the vehicle rests. The traveller is swathed in his carriage like an infant in a cradle, with a stick in his hand to steer the vessel, and disengage it from pieces of rock or stumps of tree that may happen to obstruct the route. He must also balance the sledge with his body, otherwise he will be in danger of being overturned. With this draught the reindeer, if pressed, will travel from sixty to eighty miles in a day; but more frequently he does not travel more than forty or fifty, which is a good day's journey.

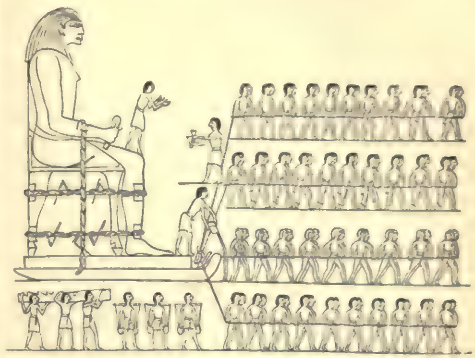
Among the Kamtschatdales, Esquimaux, and other northern tribes, a peculiar variety of dog is almost universally employed as a beast of draught, and occasionally as one of burden. These animals are trained to draw the rude sledges that the Esquimaux, for example, are able to construct, which are about five feet long and two wide. The dogs are harnessed by a collar, and a single trace running over their backs. They are not tied to each other, but each one is attached separately to the sledge, and at unequal distances, some even at twenty feet. The most docile dog is the leader, and his is the longest trace. A good leader is very attentive to the words of the conductor, and looks back over his shoulder with great earnestness to catch the word of command. Ten dogs make a full team, and will draw a sledge twelve miles an hour. On a good surface, six or seven dogs will perform in a day a journey of sixty miles, with nearly one thousand pounds to draw.

In Russia, and also in Canada, sleighs are used in winter for conveyance from place to place, the beast of draught being the horse. As the roads

in many parts of Canada are very unsuitable for any species of travelling, it happens that sleighing over the hardened surface of the snow in winter is by far the best mode of communication in that country.

From the rude sledge, drawn with an incalculable degree of labour over the rough ground, the next important step in mechanical construction is to apply wheels, for the purpose of lessening the friction of the moving body. The first application of wheels to carriages is beyond the reach of record. Wagons are spoken of in the book of Genesis, from which it may be inferred that a knowledge of wheels was common in a very early age. It is further known that the making of wheels formed a distinct trade among the citizens of Thebes in ancient Egypt, three or four thousand years ago. The most elegant of the Egyptian carriages was a kind of gig, or light open chariot, on two wheels, called the *plaustrum*, drawn by a pair of oxen instead of horses. The annexed engraving represents an Ethiopian princess, who is on her journey in such a chariot through Upper Egypt to Thebes, where the court then resided.

From the researches of Wilkinson, we are enabled to form some estimate of the enormous trouble incurred by the ancient Egyptians in the transport of the heavy stones which they employed in building their temples. Some of these blocks weighed three or four thousand tons, and were usually conveyed from the quarries from which they were cut in flat-bottomed boats on canals made for the purpose. Occasionally, however, when this mode of transport was unsuitable, the stone was drawn on sledges, perhaps some hundreds of miles, by oxen, or by human labour. The accompanying wood-cut represents, in an abridged form, the mode of conveying colossal figures in stone from the quarries to the temples in which they were to be set up. 'One hundred and seventy-two men, in four rows of forty-three each [we represent only as far as twenty each row], pull the ropes attached to the front of the sledge; and a liquid, probably grease, is poured from a vase by a person standing on the pedestal of the statue, in order to facilitate its progress as it slides over the ground, which was probably covered with a bed of planks, though they are not indicated in the painting. Some of the persons employed in this laborious duty appear to be Egyptians; the others are foreign slaves, who are clad in the costume of their country. Below are persons carrying vases of the liquid, or perhaps water, for the use of the workmen, and some implements connected with the transport of the statue, followed by taskmasters with their wands of office [but which we have not had space to include]. On the knee of the figure stands a man, who claps his



hands to the measured cadence of a song, to mark the time, and insure their simultaneous draught. The height of the statue appears to have been about twenty-four feet, including the pedestal. It was bound to the sledge by ropes, which were tightened by means of pegs inserted between them, and twisted round until completely braced; and to prevent injury from the friction of the ropes upon the stone, a compress of leather or other substance was introduced at the part where they touched the statue.'

TRAVELLING IN PAST TIMES IN BRITAIN.

The modes of travelling and conveyance in Britain were of a comparatively rude and primitive kind till the latter part of the seventeenth century; and anything like comfortable and quick travelling cannot be said to have been known till a century later, when mail-coaching was introduced. In old times, people of a humble rank travelled only on foot, and those of a higher station on horseback. Noblemen and gentlemen, as much for ostentation as use, kept running-footmen—a class of servants active in limb, who ran before them on a journey, or went upon errands of special import. The pedestrian powers of these footmen were often surprising.

When the matter of communication was of particular importance, or required to be despatched to a considerable distance, horsemen were employed; and these, by means of relays of fresh animals, and great toil of body, would proceed journeys of some hundreds of miles to accomplish what would now be much better done by a post-letter. Some journeys performed on horseback in former days would be considered wonderful even in modern times, with good roads. Queen Elizabeth died at one o'clock of the morning of Thursday the 24th of March 1603. Between nine and ten, Sir Robert Carey left London—after having been up all night—for the purpose of conveying the intelligence to her successor, James, at Edinburgh. That night he rode to Doncaster, 155 miles. Next night he reached Witherington, near Morpeth. Early on Saturday morning he proceeded by Norham across the Border; and that evening, at no late hour, kneeled beside the king's bed at Holyrood, and saluted him as king of England, France, and Ireland. He had

thus travelled 400 miles in three days, resting during the two intermediate nights. But it must not be supposed that speed like this was attained on all occasions. At the commencement of the religious troubles in the reign of Charles I. when matters of the utmost importance were debated between the king and his northern subjects, it uniformly appears that a communication from Edinburgh to London, however pressing might be the occasion, was not answered in less than a fortnight. And even till the last century was pretty far advanced, the ordinary riding-post between London and Edinburgh regularly took a week to the journey.

In consequence of the inattention of our ancestors to roads, and the wretched state in which these were usually kept, it was long before coaching of any kind came much into fashion. Though wheeled vehicles of various kinds were in use among the ancients, the close carriage or coach is of modern invention. The name *coach* is most probably from the French *coucher*, to lie, as if signifying originally a litter or carriage in which you may recline. The earliest record found by Beckmann relates to about the year 1280, when Charles of Anjou entered Naples, and his queen rode in a *caretta*—apparently a small but highly decorated car, from which the modern *charet* or *chariot* was derived, as well as other vehicles named *chares* and *chariettes*. It is believed that most of these vehicles had broad wheels, the only form suited for the wretched roads of those ages; and it is certain that all those of early date were open overhead. Many of the coaches used by the continental princes and nobles in the 16th century were closed only to this extent—that they had canopies supported by ornamental pillars, and curtains of cloth, silk, or leather, which could be drawn easily aside. A *glass* coach, or coach with glass windows, is specially mentioned as being used by an Infanta of Spain in 1631. The traces of the coaches were at first made of rope; those only belonging to the highest personages were made of leather. It is believed to have been in the time of Louis XIV. that coaches were first suspended by leathern straps, in order to insure ease of motion.

The first coach ever seen in England is said to have been one made in 1555 by Walter Rippon for the Earl of Rutland; and in 1564, the same builder made a showy vehicle for Queen Elizabeth.

State Carriage of Queen Elizabeth:
(From Hoefnagel's print of Nonsuch Palace).

Later in the reign, the royal carriages had sliding panels, so that the queen could shew herself to her loving subjects whenever she desired. During the closing years of Elizabeth's reign, and early in the 17th century, the use of pleasure-carriages extended rapidly in England. The coaches had first to struggle against the opposition of the boatmen on the rivers, and then against that of the sedan owners and bearers; but they gradually came into very general use. Lord Grey de Wilton, who died in 1593, introduced a coach into Ireland, the first ever used in that country. One was introduced into Scotland—we rather think from France—about the year 1571. It belonged to the famous Secretary Maitland of Lethington, who, during the civil war between the adherents of Mary and those of her son James, made a journey in that vehicle from Edinburgh Castle, which he was holding out for the queen, to Niddry in West Lothian, for the purpose of consulting with some others of her friends—the first time, it is believed, that a close carriage was ever used in Scotland. Fynes Morison, who wrote in the year 1617, speaks of coaches as recently introduced, and still rare in Scotland.

In a pamphlet called *The Grand Concern of England Explained*, published in 1673, the writer very gravely attempts to make out that the introduction of coaches was ruining the trade of England. The following is an example of his mode of reasoning: 'Before the coaches were set up, travellers rode on horseback, and men had boots, spurs, saddles, bridles, saddle-cloths, and good riding-suits, coats and cloaks, stockings and hats, whereby the wool and leather of the kingdom were consumed. Besides, most gentlemen, when they travelled on horseback, used to ride with swords, belts, pistols, holsters, portmanteaus, and hat-cases, which in these coaches they have little or no occasion for. For when they rode on horseback, they rode in one suit, and carried another to wear when they came to their journey's end, or lay by the way; but in coaches they ride in a silk suit, with an Indian gown, with a sash, silk stockings, and the beaver hats men ride in, and carry no other with them. This is because they escape the wet and dirt which on horseback they cannot avoid; whereas in two or three journeys on horseback, these clothes and hats were wont to be spoiled; which done, they were forced to have new very often, and that increased the consumption of manufacture.'

Arguments of a similar illogical nature are now used in reference to almost every proposed

melioration in our social condition, and will doubtless, in a century hence, be quoted for their short-sighted folly, though at present meeting with countenance from a large class of the community.

Notwithstanding the introduction of stage-coaches in the seventeenth century, they were placed only on the principal roads, and used almost exclusively by persons of refined taste and wealth. The popular mode of conveyance continued for at least a century afterwards to be by stage-wagons; these were very large and cumbersome machines, drawn by six or eight horses, and devoted chiefly to the carriage of goods to and from the metropolis. The only part of the vehicle which afforded accommodation to passengers was the tail of the wagon, as it was called, a reserved space with a hooped-up cover at the hinder part of the machine; and here, sitting upon straw as they best could, some half-dozen passengers were slowly conveyed—we should rather say jolted—on their journey.

The wagons thus employed in the double office of carrying both goods and passengers were, as we have said, confined chiefly to the great lines of road in England. On all the less important routes, and particularly in Scotland, the only means of conveyance for goods was by pack-horses.

These animals were loaded with sacks thrown across the back; and if not too heavy, piled to a considerable height. A number together were generally conducted in a line along the narrow and badly constructed paths, that which went before carrying a bell, by the tinkling sound of which the cavalcade was kept from straggling after nightfall. This primitive mode of conveyance continued in operation in some parts of the country till the year 1780 or thereabouts, when one-horse carts came into use.

The length of time consumed in journeys by even the best kind of carriages of past times, is now matter for surprise. The stage-coach which went between London and Oxford in the reign of Charles II. required two days, though the space is only fifty-eight miles. That to Exeter (168¼ miles) required four days. In 1703, when Prince George of Denmark went from Windsor to Petworth to meet Charles III. of Spain, the distance being about forty miles, he required fourteen hours for the journey, the last nine miles taking six. The person who records this fact says, that the long time was the more surprising, as, *except when overturned*, or when stuck fast in the mire, his Royal Highness made no stop during the journey.

In 1742, stage-coaches must have been more numerous in England than in Charles II.'s time; but it does not appear that they moved any faster. The journey from London to Birmingham (116 miles) then occupied nearly three days.

Of the stage-coach journey to Bath about 1748, we learn some particulars from Smollett's celebrated novel. Mr Random enters the coach before daylight. It proceeds. A highwayman attacks it before breakfast, and is repulsed by the gallantry of the hero. Strap meanwhile accompanies the coach on horseback. A night is spent on the road, and the journey is finished next day, apparently towards evening—108 miles! At that time there was no regular stage-coach from London to Edinburgh; and the newspapers of the latter city occasionally present advertisements, stating that an individual about to proceed to the metropolis by a post-chaise would be glad to hear of a fellow-adventurer, or more, to lessen the expenses for mutual convenience. However, before 1754, there was a stage-coach between the two British capitals, as appears from an advertisement in the *Edinburgh Courant*. The journey occupied twelve days, being at the rate of thirty-three miles a day. So lately as the end of the last century, the journey by the stage between Edinburgh and Glasgow (forty-two miles) occupied a whole day, the passengers stopping to dine on the road. It was considered a great improvement when, in 1799, a coach was started with four horses which performed the journey in six hours.

ROADS.

It will appear, from the preceding notices respecting travelling and modes of carriage for goods, that little or no improvement could be expected in either case till a great change for the better was made on the state of the roads. In no branch of art do our ancestors seem to have been more deficient or heedless than in that of making roads, and keeping them in constant repair. In this respect, indeed, they were in a condition of greater ignorance than the ancient Romans, whose roads were on the most extensive and efficient scale, suitable to the necessities of the period, and may here be shortly described.

Ancient Roman Roads.

The Romans are entitled to be called the first and best road-makers of whom history has preserved any account. One great leading principle actuated the Roman authorities in establishing roads: it was that of maintaining their military conquests.

Speaking of the subordinate Roman capitals in Asia Minor, Syria, and Egypt, Gibbon describes as follows the manner in which they were connected by roads: 'All these cities were connected with each other and with the capital by the public highways, which, issuing from the Forum at Rome, traversed Italy, pervaded the provinces, and were terminated only by the frontiers of the empire. If we carefully trace the distance from the wall of Antoninus [in Scotland] to Rome, and from thence to Jerusalem, it will be found that the great chain of communication, from the north-west to the south-east point of the empire, was drawn out to the length of 4080 Roman [or 3740 English] miles. The public roads were accurately divided by milestones, and ran in a direct line from one city to another, with very little respect for the

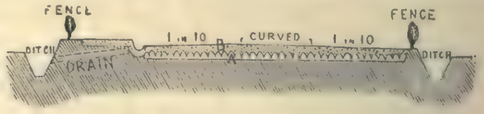
obstacles either of nature or private property. Mountains were perforated, and bold arches thrown over the broadest and most rapid streams. The middle part of the road was raised into a terrace which commanded the adjacent country, consisting of several strata of sand, gravel, and cement, and was paved with large stones, or, in some places near the capital, with granite. Such was the solid construction of the Roman highways, whose firmness has not entirely yielded to the effect of fifteen centuries. They united the subjects of the most distant provinces by an easy and familiar intercourse; but their primary object had been to facilitate the marches of the legions: nor was any country considered as completely subdued, till it had been rendered in all its parts pervious to the arms and authority of the conqueror. The advantage of receiving the earliest intelligence, and of conveying their orders with celerity, induced the emperors to establish throughout their extensive dominions the regular institution of posts. Houses were everywhere erected, at the distance of only five or six miles; each of them was constantly provided with forty horses; and by the help of these relays, it was easy to travel a hundred miles in a day along the Roman roads. The use of the posts was allowed to those who claimed it by an imperial mandate; but though originally intended for the public service, it was sometimes indulged to the business or conveniency of private citizens.'

From other accounts, we learn that the Roman roads varied in importance and uses. The great lines were called *prætorian ways*, as being under the direction of the prætors; and these formed the roads for military intercourse. Other lines were exclusively adapted for commerce or civil intercourse, and were under the direction of consuls. Both kinds were formed in a similar manner. First, all loose and soft matter was removed, and then a solid substructure was laid, consisting of several strata of small stones, broken tiles, and gravel, concreted by cement. Above this was laid the pavement, formed of large hexagonal blocks of stone, jointed together—in the principal roads at least—with care. Basaltic lava seems to have been preferred, when it could be had. Various remains of Roman roads of this kind still exist in Italy, France, and also in different parts of Britain. One of the chief Roman thoroughfares, in an oblique direction across the country from London to the west of Scotland, was long known by the name of Watling Street, which has been perpetuated in the appellation of one of the streets in the metropolis.

Modern Roads.

The Roman roads being constructed not for wheeled carriages, but for marching and for beasts of burden, were carried straight from one station to another, without any regard to the level. With modern roads, the case is altogether different. In fact, the skill and ingenuity of the modern road engineer are directed to make the inclinations or gradients, as they are called, easy, with as little expense as possible in excavating and embanking, and to do this without deviating much from the direct course.

What is the best transverse form for a road, is a much debated question among engineers. All agree that it should be higher in the middle than at the sides, but some think it should be much higher than others. As a road can be better kept clear of water by a slight inclination in the direction of its length, than by any form which can be given to its cross section, it seems preferable that it should be as nearly flat as possible, because every part of its breadth will then be equally available for traffic; whereas it is almost necessary to keep on the centre of a highly convex road, and consequently wear deep furrows there, by confining the wheels and horses to pretty much the same track. The figure shews a transverse



Cross Section of a Road:
A, Foundation of rough pavement or concrete; B, Broken stones.

section of a road of an approved form; the slope is 1 in 30, with a few feet in the centre on a flat curve.

In the construction of the road itself, there are two rival systems, the essential point of difference being whether a hard, firm foundation is necessary or not. Telford considered the foundation of primary importance, and constructed it of rough stones, carefully set on their broad edges, and having the interstices packed by hand with stone chips, thus forming a solid pavement. Macadam, on the contrary, held it to be a matter of indifference whether the substratum be hard or soft; he even preferred a yielding and soft foundation to one which was rigid and unyielding, so that even on boggy ground, if it were but firm enough to allow of a man walking over it, he considered an artificial bottoming quite unnecessary. His roads were formed entirely of angular pieces of stone, of such a size as to pass freely through a ring 2½ inches in diameter. This plan has now fewer advocates than Telford's, or than the one subsequently proposed by Mr Thomas Hughes, where a concrete of gravel and lime is employed for the foundation of the road. But experience has shewn that Macadam's plan of employing angular pieces of stone is superior to every other as a mere covering for roads, whether they have an artificial foundation or not. So popular at one time was the system of macadamising, that expensively paved streets, such as that between Edinburgh and Leith, were torn up to be reformed on the new plan. Dublin has been instanced as an example of the failure of Macadam's plan for the streets of a populous city. There the macadamised streets are in winter constantly covered with mud, and in summer, profuse watering is required to keep them from being overwhelmed with dust. It is curious, however, that the French road-engineers have, in recent years, come to the conclusion, that a covering of broken stone alone is sufficient on the most frequented roads and under all but the very heaviest traffic.

With regard to the kind of stone suitable for covering roads, granite and the different kinds of greenstone and basalt, ordinarily called whinstones, are the only kinds admissible. Sandstone is too easily crushed, limestone is objectionable from its slight solubility in water. The stone

employed should be tough as well as hard. Flint is hard enough, but it is brittle, and easily crushed to powder. The object is to get it to bind into a firm mass, and not to roll about, after it has been laid down for some time.

With respect to the maintenance of roads, the trustees appointed by local acts of parliament to superintend highways, now generally employ contractors to keep the roads in repair at a specified price per mile. The cost of maintenance, interest on capital, &c. are usually defrayed from a tax levied at the toll-bars or turnpikes.* To say nothing of the annoyance of the system, this mode of raising the necessary funds is the most wasteful that could be contrived; on an average, 44 per cent. is absorbed in collection alone. In 1845, Mr Pagan, a Scottish country solicitor, proposed a plan for the entire abolition of toll-bars, the consolidation of trusts, and the levying of an annual rate on horses, or an assessment on lands and heritages. He demonstrated, taking the county of Fife as an example, that on his plan the roads could be maintained at little more than one-half their present cost. Years elapsed before any steps were taken. Ireland led the way in toll-reform; and by 1857 the whole system had disappeared in that part of the kingdom. From time to time various Scottish counties obtained acts for themselves for abolishing toll-gates, and many English Local Government Boards have adopted a similar course. The Roads and Bridges (Scotland) Act of 1878 provided for the abolition, within a few years, of all remaining tolls in Scotland.

Law of the Road.—For general convenience and safety, drivers of vehicles and riders, in travelling along a road, are expected to take a particular side; and this practice is now so well understood, and is in itself so proper, as to have become a part of the common law. The law of the road is, that when drivers meet from different directions, each shall keep his left hand to the wall or footpath. Secondly, when one driver overtakes another, and wishes to pass him, he must keep his left hand to the vehicle which he passes. In the case of either meeting or passing, each party is entitled to the half of the road. The same rules apply to riders. If these regulations be neglected, and an accident occur, the law is always in favour of the party who kept his own proper side, and no excuse can shelter the aggressor. The trustees of the road are liable in an action of damages for any injury that may be sustained through the carelessness of themselves or servants in leaving the road grossly out of repair.

According to a well-known rule, foot-passengers on pavements or side-paths adopt a plan just the reverse of this; that is, they are expected to keep their left hand to those whom they are meeting and passing. This custom prevents confusion in the streets of large towns, but is not a matter of law.

CANALS.

A canal is an artificial channel of water, and is usually constructed for inland navigation. Where rivers can be resorted to for purposes of this kind, they are preferable to canals, because little expense may be required to suit them for navigation, and they may be easily kept in repair. But few rivers, generally speaking, are sufficiently level, straight, or deep, to admit of being profitably navigated by barges, and therefore artificial channels require to be cut. Canals are extremely suitable in level countries possessing rivers or brooks which can afford a due supply of water. In China, from a very early age, certain large rivers have formed natural canals longitudinally through the country from west to east, while artificial canals have been made to proceed in a cross direction from north to south, thus effecting a universal water-communication throughout the empire. Canals existed in ancient Egypt in connection with the Nile, on a similar plan to what now prevails in China. Notwithstanding that canals were known to have existed from a remote antiquity in the East, it was long before they were introduced into Western Europe. In modern times, they were first used by the inhabitants of the Netherlands, in consequence of the extreme flatness of their country, and the numerous channels of water which intersect it in all directions. As vehicles of transport, canals can never answer as profitable speculations when they have to compete with coasting-vessels of any description, or with any species of conveyance by rivers. They cannot even, in certain circumstances, compete successfully with railways, on account of the slowness of speed at which barges or boats are drawn along them; and as speed is becoming daily a matter of greater moment in traffic, canals are, for the most part, gradually losing the conveyance of every kind of goods for which quickness of transit is desirable.

In order to meet the requirements of modern commercial traffic, in which *speed* is an essential feature, attempts have been recently made to adapt steam-power to canal traction, but with very limited success. It may not be generally known that the principal obstacle to the use of steam-engines on board canal-boats is the injury done to the banks by the action of the water from the paddles. This obstacle has to a certain degree been overcome by the use of one-paddled boats—the paddle being placed in the line of the boat's keel; and also by the application of the Archimedean screw-propeller. Still, steam-dragging is by no means general; and canals, as a superseded idea, do not now much occupy the attention of engineers and inventors.

One of the largest canals in Europe is that which extends from the German Ocean to the river Y, at Amsterdam, by which vessels are enabled to reach that city by a direct channel, instead of sailing round by the Zuiderzee. This ship-canal was begun in 1819, and finished in 1825, at an expense of £850,000. Its length is nearly 52 English miles; its breadth 128 feet at the surface, and 38 feet at the bottom; and its depth 20 feet. It has five locks, each 190 feet long, and 24 broad. A new ship canal, which shortens the distance from Amsterdam to the North Sea to 15 miles, was finished and opened in 1876. The harbour is near Wyk-aan-Zee. The minimum width is 80 yards.

The greatest canal yet executed is that cut

* Turnpikes were so called from poles or bars, swung on a pivot, having been placed on them, and turned either way when dues were paid. Gates are now substituted for these poles in Great Britain. In Germany, the pole is still used, one end being depressed to raise the other, and so permit a free passage.

through the Isthmus of Suez from Port Said on the Mediterranean, to Suez on the gulf of that name. The length is 100 miles; the width at bottom, 26 yards; and the depth of water, 26 feet. The soul of the scheme was M. de Lesseps, a French engineer, who organised a company for the undertaking in 1855, and after fourteen years of indefatigable exertion, saw the canal formally opened for traffic in November 1869. It is found to afford an easy and expeditious passage to the largest ships from Europe to the Indian and Australian seas; British shipowners use it extensively.

A still more stupendous enterprise was the Panama Canal, also due to the inexhaustible energy of M. de Lesseps, and designed to connect the Atlantic and South Pacific across the Isthmus of Panama. It was begun in 1881.

In ancient times there was a canal from Suez to Bubastis, on the eastern branch of the Nile, begun 600 B.C., and finally overwhelmed 767 A.D.

France possesses about fifty different canals, some of which are of great importance for general traffic. The chief canal is allowed to be that of Briare, called also that of the Loire and Seine. It was completed in 1642, measures 34½ miles in length, and has 40 or 42 locks. The width is 25 feet at bottom. By this canal, Paris receives large supplies of inland produce. The Canal du Midi, or Languedoc Canal, makes a communication between the Mediterranean at the city of Cette and the Atlantic Ocean at the mouth of the Garonne, passing through the province of Languedoc. Altogether, there are nearly 1000 miles of canals in France.

The United States of North America possess upwards of 2500 miles of canals. The principal undertaking of this kind is the Erie Canal, which unites the river Hudson at Albany with Lake Erie at Buffalo, a distance of 363 miles. The Miami Canal, from Cincinnati to Lake Erie, which extends 265 miles, is another great undertaking; and there are a number of other canals, scarcely less important, for the general traffic of the country. The canals of Canada are also on a great scale. The Rideau Canal, 135 miles long, connects the town of Ottawa—formerly Bytown—on the river Ottawa, with Kingston on Lake Ontario. By means of the Welland Canal, 28 miles long, connecting Lakes Erie and Ontario, and of the St Lawrence Canal, 41 miles in length, for avoiding the rapids of that river, communication is now open, for sea-going vessels, from the Atlantic to the most western ports on the Canadian lakes. In 1856, for the first time, a cargo of wheat was brought from Chicago to Liverpool without trans-shipment.

The canals of Great Britain are believed to extend to an aggregate length of 4700 miles. The greater part are in the midland districts of England, including Lancashire, and have for their object the connection of the large seats of manufacture with the sea on both sides of the island, and with the Thames at London. The Grand Trunk Canal, connecting the Mersey with the Trent and Humber, extends 93 miles. The Birmingham and Worcester connects the Grand Trunk Canal with the Severn. The Grand Junction connects the Grand Trunk with the Thames. Thus the four great ports of the kingdom—London, Bristol, Liverpool, and Hull—are connected by canals. So generally are these and other canals spread over England, that it is supposed there is not a place south of Durham more than fifteen miles from water-communication.

Ireland has about 300 miles of canals, mostly government undertakings, and in general possessed of little trade. Scotland has a number of canals, but they are chiefly confined to the western and mid district of the country. That which possesses the largest traffic is the Forth and Clyde Canal, reaching from the Clyde, a short way above Dumbarton, to the Forth at Grangemouth. This canal, which was opened in 1790, and affords a ready communication for small vessels between the east and west coast, extends 39 miles in length; its highest level is 160 feet, with 20 locks on the eastern acclivity, and 19 on the western. The canal is connected with Glasgow by a side-cut; and it is joined by the Union Canal, which extends from near its eastern extremity to Edinburgh. The Caledonian Canal was constructed to avoid the dangerous and tedious navigation round by the Pentland Firth and the Hebrides; the distance from Kinnaird's Head to the Sound of Mull by this route being 500 miles, and by the Canal, 250 miles. The Great Glen of Albin, or Glenmore, in Inverness-shire, running from the Moray Firth, south-west quite across the island, is in great part occupied by a chain of natural lakes; and it only remained to connect these by cuttings to form a magnificent water-way. The canal begins in the Beauly Firth, near Inverness, and joins Loch Eil, an inlet of the Atlantic, near Fort-William. The whole length of the navigation is 60½ miles; of this, 37½ miles are occupied by the three lakes or lochs—Ness, Oich, and Lochy, and the remaining 23 miles by four cuts or canals. The canals are 120 feet broad at surface, and 50 at bottom, and 17 deep. The practicability of this great work was first shewn by a survey under government in 1773 by the celebrated James Watt; but it was not till 1803 that it was begun under Mr Telford. The whole line was opened for ships in 1823. After three years of repair, it was re-opened in 1847. Ships of 500 to 600 tons, fully laden, can pass through the canal. The canal and tonnage rates for sailing-vessels are each a farthing per mile per ton, and a half of this for vessels under 125 tons. Steamers pay 2s. a ton. Of £1,368,203 expended on this canal, from 1803 to 1856, £1,242,387 were voted by parliament, and £90,748 were from canal dues. Only in a few years have the receipts equalled the expenditure. In the year ending April 1881, the receipts were £7498; and the expenditure (including repairs), £7726—an unusually favourable state of matters.

RAILWAYS.

The origin of the modern railway undoubtedly belongs to Britain, and is traced to a contrivance adopted for simplifying the transit of coal from the mines in Northumberland and Durham to the places of shipment. The invention consisted of two parallel lines of wooden beams fixed to the ground, and furnished with flanges to prevent the wheels of vehicles slipping aside. Along these ways wagons were drawn by horses with such comparative ease that they soon became popular. From less to more, this contrivance led to the modern railway; nor is it useless to note that the

invention in its early stages was mainly the work of uneducated mechanics.

The date of the invention of tramways is uncertain, but by good authorities it is referred to the period between 1602 and 1649. From the northern coal districts, it gradually came into use in other mining districts in England, as also in the south of Scotland. It was not till about 1700 that there was any marked advance on the original tramway. The first step was the clothing of the wooden beams with long slips of iron. This also being found defective, a second improvement, about 1740, was the substitution of cast-iron rails fixed on cross wooden sleepers. These cast-iron rails or trams had a flange on the inner side, and having been first laid by Outram, it is said these ways were then called *tram*-roads; but it is as likely that the name was derived from the word trammel.

The use of cast-iron rails led to an improved method of traction. Instead of employing a single large wagon, the plan of linking together a series of smaller wagons was adopted—the germ of the modern train.

The form of tram described above was found to collect dust and gravel. To obviate this, Jessop, in 1789, laid down *edge*-rails of cast-iron, and guided the wheels by applying a flange round their edge. This was the first system of rails laid on cast-iron chairs and sleepers, and to which the present system is very similar. The brittleness of cast-iron and the frequent breakages would have stood in the way of the use of railways for the conveyance of passengers at high speeds; but before this was attempted, Birkenshaw, in 1820, patented a great improvement, by substituting rolled wrought-iron for cast-iron. The draught still continued to be executed by horses. Watt had shewn the practicability of fixed steam-engines; what was now wanted was an engine that would travel by its own internal impulse. The merit of inventing a self-acting steam-carriage is allowed to be due to Richard Trevethick, a clever but eccentric engineer; he was the first who practically applied it to work on roads and railways. In 1802, he took out a patent for a steam-carriage, and this novel machine he exhibited to large and astonished crowds in London. Immediately afterwards, he adapted his steam-carriage for the drawing of wagons on railways, a duty which it successfully executed on the Merthyr-Tydvil Railway in 1804. This was the first railway locomotive; but it was far from perfect. It drew only ten tons of bar-iron at the rate of 5 miles an hour. Trevethick did not remain in England to improve on his invention, nor was there for some time any distinct advance on his ingenious contrivance. The principal cause of this lethargy seems to have consisted in a universal belief among engineers, that the locomotive could not be expected to gain great speed, to ascend a moderate incline, or to draw a heavy load, unless provided with cogged wheels to work into a corresponding rack laid along the rails. Numerous attempts were made to overcome this imaginary difficulty; but none were successful. A curious mountain-line constructed on this principle in 1871, has proved a great commercial success. That locomotives running with smooth wheels on smooth rails, by mere weight and friction or adhesion, as exemplified by Trevethick, could draw heavy loads up a moderate incline, was, in 1811, established as a fact by Mr Blackett, a coal proprietor, on the Wylam Railway. The means of imparting speed alone remained to be found.

Locomotive power was employed by George Stephenson on the Killingworth Railway in 1814, and with such success that it was afterwards applied on the Stockton and Darlington Railway, for which the first act of parliament was passed in 1821. In this last undertaking, Stephenson was encouraged by the generous and enlightened aid of Edward Pease, a member of the Society of Friends. The Stockton and Darlington was the first railway in which carriages travelled with passengers; yet, even with the measure of success so secured, the locomotive was still an imperfect machine, for its rate of progress continued to be little faster than the walk of a horse.

It certainly seems very strange, that notwithstanding the proved feasibility of railways, the public at large could not be stimulated to give any heed to the subject. The idea of extending railways over the kingdom for general traffic, was perhaps first conceived by Thomas Gray of Nottingham, who, full of enthusiasm, besieged the public, and memorialised the government on this his favourite project, between 1820 and 1824. A work embodying his views, *Observations on a General Iron Railway, &c.* was published in 1820. Gray's ardent notions met with little favour. After Gray, there appeared another projector, William James of London, who, in 1822, endeavoured, without success, to establish a railway between Liverpool and Manchester. Opposition caused his plans to be laid aside. The next and more fortunate projector was Joseph Sanders of Liverpool. He issued the prospectus of a railway from Liverpool to Manchester, 29th October 1824; and this line, surveyed by Stephenson, was, after much unworthy opposition, and some changes of route, sanctioned by the legislature. The projectors of this railway at first thought of using horses, stationary engines, &c.; but finally deciding in favour of the locomotive, offered a premium for the best. The trial was fixed for October 1829; and the 'Rocket,' constructed by the Messrs Stephenson and Mr Booth, of the Liverpool and Manchester Railway, was most successful.

This, then, was the first high-speed locomotive; it weighed 4 tons 5 cwt.; and with a gross load of 17 tons, averaged a speed of 14 miles per hour, its maximum speed being 29 miles. The success of this locomotive was due to the introduction of the multitubular boiler, together with the simple contrivance of leading the exhaust steam up the chimney, and so creating a strong draught, both combining to increase to an unprecedented extent the evaporating power of the boiler. Thus acceleration—the grand desideratum—was attained. The Liverpool and Manchester line was formally opened for traffic, September 15, 1830, and provided with Stephenson's locomotives, its success was immediate and complete—in fact, the great railway system was inaugurated.

Now, properly speaking, began that course of commercial enterprise, unregulated, and often wasteful, which has since assumed such importance. Refraining from all control over railway operations, the government left speculators to carry lines anywhere or anyhow that parliament could be persuaded to sanction. The result, as is well known, has been in many places a complication of

competing lines on no principle of economy or enlightened foresight. Abandoned, as it were, to the audacity of promoters, and the mere brute-force of capital, schemes good, bad, and indifferent had to fight their way at a cost almost exceeding belief; while at the same time there has been much waste of money in allowing circuitous lines to be laid, which are afterwards, in a great measure, superseded by others more direct.

LEGISLATION AND MANAGEMENT. — In the United Kingdom, railways are the property of independent companies, who construct and work them under the provisions of acts of parliament. The first step consists in organising a company. Generally a solicitor and a few active projectors draw up a prospectus, call meetings, suggest the names of directors, and appoint an engineer to make a survey. In no case does government or any public body take any part in the initiatory proceedings, or find any part of the capital. By the engineer and solicitor there is much to be done at the outset. The solicitor has to discover the name of every proprietor whose land is interfered with, as well as every tenant or occupant; all which names, with the extent and nature of the land to be taken, are entered in a roll, called the *Book of Reference;* and with every person so concerned a schedule must be lodged stating all particulars, with a request to state in reply whether they design to assent, to oppose, or to remain neutral. Land to be taken for, or damaged by, railways is valued under different categories: 1. The quantity and quality; 2. The injury caused by cutting off one part of a field from another; and 3. The damage done to the amenity or beauty of the place. Provision must of course be made for not interfering with the ordinary roads and water-courses. Should the lands be let to a farmer, as is very generally the case, he is treated with separately for the loss he is likely to sustain during his lease. At one time, enormous sums were asked and paid for alleged damage to land; now, the claims are more moderate, and in few instances is damage to amenity an element of consideration.

Until a statutory enactment is procured, the shares of a company are in that embryo state called *scrip.* Allotted to applicants by the provisional directors, the shares are 'taken up' by paying a small instalment, of from 5*s.* to 20*s.* per share. These preliminary sums are paid in to a specified bank, the receipt of which is the scrip or certificate that so frequently becomes the subject of eager transfer among jobbers. The bank deposits of the allottees constitute the fund from which are paid all preliminary expenses. Should the bill become law, scrip-holders are required to present their names with the amount of their respective shares for register at the office of the secretary of the company. 'Calls' are next made on the shareholders. If the shares be £10, a call of £2, 10*s.* per share, at intervals of three months till the whole is paid, is customary. Any failure to pay calls by a prescribed day incurs the risk of forfeiture. In authorising a company, parliament gives power to raise so much money by shares, and so much by borrowing. The amount that may be borrowed is equal to a third of the stock, but it cannot be legally borrowed until all the shares have been issued, and at least one-half of all the shares have been paid up. The lender has a mortgage over the whole property of the company, called a debenture. The entire amount paid for shares and borrowed on mortgage forms the 'capital account' of the company.

The act which authorises the undertaking constitutes the company a corporation, the members of which are responsible only to the extent of their respective shares. In the act, the names of the first directors are given; it is also stated who are first to retire, and how elections are to be conducted. A director must possess a prescribed amount of stock. The directors have the appointment of secretary, traffic-managers, and other paid officials. The directors themselves profess to give their services without remuneration; but the shareholders usually vote a sum to be put at their disposal, at least adequate to meet absolutely necessary expenses. Where the duties are very onerous, a special allowance per annum is voted to the chairman.

The organisation of the present railway system has not depended on the private acts authorising the several undertakings. There is now a body of general railway law, springing from a number of public acts which have from time to time received the grave consideration of the legislature. These statutes date from 1838 downwards; some of the more important were passed in 1845, among these being several comprehensive statutes, including 'The Companies Clauses Consolidation Act,' also 'Railway and Lands Clauses Consolidation Acts,' which have been supplemented from time to time. See Bigg's *General Railway Acts.*

Besides these public acts, there is a code of regulations as regards the mode of commencing and carrying railway bills through the Houses of Parliament. This code, embodied in a work issued annually, is styled *Standing Orders of the Lords and Commons relative to Private Bills.* With this, all parties engaged in procuring railway acts require to be well acquainted, for neglect of any of the prescribed forms is almost certain to be fatal. We give the following as specimens of 'Standing Orders:' Notices of applications for acts to be advertised in October or November; plans, sections, and books of reference to be lodged with clerk of the peace or sheriff-clerk of county for public inspection, on or before 30th November; petitions for act stating particulars to be lodged at the Private Bill Office of the House of Commons on or before 23d December; on or before same date, copy of proposed bill to be lodged with Board of Trade, &c. There are equally explicit standing orders as regards the House of Lords, whose chairman of committees subjects all private bills to a sifting examination. Whatever, therefore, may have been the negligence of the government at the outset, railway legislation has latterly received a painful degree of attention. As marking a desire for simplifying procedure and lessening expenses, parliament passed an act, 1864, giving the Board of Trade power to authorise bills for a smaller class of railways, provided they were unopposed.

Railways soon exhibited a wonderful elasticity and creative power. To inland and not easily reached towns they impart the character of a seaport, placed in ready communication with all the world. The exciting of a desire to travel, and the developing of local trade and resources, accordingly attend on railway undertakings, and the

consequence is a universal activity and prosperity, and the creation of wealthy industrial centres.

Railways were at first detached undertakings between one large town and another, but now many of the companies have for mutual advantage amalgamated in groups; and in a number of cases, for economy in working, lesser lines have been leased to companies of larger means. One of the advantageous results of a union of railway interests is, that passengers are able to procure 'through-tickets;' but it is not less conspicuous that the 'railway interest' has become a formidable power in the state, and is able to carry lines almost anywhere, in disregard of every other interest, public or private. Making every allowance, therefore, for the high social value of the railway system, it has certainly reached a point of despotic overbearance that requires some species of control more effectual than that which has hitherto been embraced in the irregular action of parliamentary committees or of the Board of Trade. This question has lately been attracting much attention. The government has tried in various ways to ameliorate the evils arising from its early apathy, and to control the excesses of railway enterprise. One of these efforts was the appointment of a Joint Committee of Lords and Commons in 1872. This committee reported among other things: 'That no means have yet been devised by which competition can be maintained. Nor is there any reason to suppose that the progress of combination will cease until Great Britain is divided between a small number of great companies.' So far is this the case that four companies are virtually the owners of more than 6000 miles of railway, of which above 2000 belong to the Great Western.

An act passed in 1873 sanctions the appointment of a mixed tribunal—composed of three eminent men—for the regulation and control of the working of railways.

The only alternative proposed to the present system is the government purchase of railways. An act of parliament was passed in 1844 for the purpose of enabling government to purchase all lines after they had respectively been 21 years in existence, dating from the passing of the act. This statute came into operation in 1865; but the Joint Committee of 1872 report that they do not think the terms of the 1844 act suited to the present condition of railway property, or ever likely to be adopted by parliament. The Committee are right so far, nothing having since been done in this direction; and it may be regarded as practically abandoned.

There is much to be said on both sides of this question; most of the arguments advanced *pro* and *con.* may be found in articles respectively in the *Quarterly Review* and *British Quarterly Review*, April 1873.

CONSTRUCTION.—By far the greater number of railways in the United Kingdom consist of two lines of rails—an *up*-line conducting towards, and a *down*-line leading from, the metropolis or principal centre of traffic. Single lines, with places where trains may pass each other, are mostly of recent construction, and have received their chief development in Scotland. On some of the main lines to London, it has been found necessary to add a third, and in some cases a fourth line to accommodate the enormously increased traffic. Whether double or single, all the lines are enclosed by fences, walls, ditches, &c.

Stations.—At the chief terminus there is a group of buildings for offices, workshops, sheds for locomotives, &c. Within late years, the terminal stations at the larger towns have assumed vast proportions, and in them comfortable waiting and refreshment rooms are provided. In many cases, also, hotels on a very large scale have been erected as part of the buildings at the termini.

Signals.—The signalling arrangements form an important part of railway construction. The most common form of signal is the semaphore, and at night, coloured lights. A red light signifies danger; a green, caution; and a plain light, that the line is clear. Much care is given to the arrangement and construction of crossings, junctions, &c. with their numerous *switches*, or movable rails, used for changing the direction of a train from one line to another. The *switches* are generally worked directly from the signal-stations, and are so arranged that their points shall *not* face towards the advancing traffic. Numerous accidents have been caused by 'facing points.' Many improvements have been lately introduced in signalling, crossings, &c. all with a view to increased safety. The 'block' system has been adopted by the principal railway companies, particularly in the neighbourhood of busy centres of traffic. Under this system each signal-station is in direct telegraphic communication with the nearest signal-stations, both up and down the line, and a train is not allowed to pass any signal-station until the train immediately preceding it has started from the next station in advance. Thus the driver may push on without hesitation from point to point; and thereby the traffic is expedited, and at the same time safety increased. The system of *interlocking* has also been extensively introduced. Under this system, the pointsman can *only lower one* signal—namely, that which corresponds to the line which, from the position of the switches, is *clear;* and before he can alter the position of the switches, he is compelled to return this signal to 'danger.'

The construction of a railway is the business of contractors, who execute the works by estimate, according to the plans and specifications of the engineer. A railway contractor is a capitalist, with a practical knowledge of embanking, tunnelling, erecting bridges, &c. He possesses a stock of the various necessary apparatus, light rails, tools, &c.; including horses, wagons, and one or more locomotives for dragging materials. He has subordinates called time-keepers, foremen, gangers, and under-gangers, placed over detachments of operatives. These operatives are a remarkable class of men. Originally from Lincolnshire and Lancashire, they are popularly known as *navvies* (contracted from 'navigators'), from having been engaged in excavating navigable canals. Navvies sometimes labour in bands, called *butty-gangs*, by piece-work, and are known to draw large sums, but more generally they are employed at days' wages.

Curves and Gradients.—Engineers endeavour to render their lines as level and straight as possible, but circumstances often necessitate the use of considerable curves and gradients. As a general rule there are few curves of less than three-eighths of a mile, or 30 chains' radius; when

they are employed, the exterior rail is superelevated, to counteract the centrifugal force, otherwise a quickly moving train might leave the rails. Gradients being expensive to work according to their degree of inclination, few are more steep than 1 in 60, though 1 in 30 is not unknown. On steep gradients, stationary engines were sometimes employed, but in nearly every case these have been abandoned for locomotive power. On local and private lines, much steeper gradients and sharper curves are common. One of the earliest, if not the first trial of a locomotive on an incline of 1 in 12, was made in Scotland, in 1862, by Mr George Gray, on his private line near Bathgate.

Gauge and Earthworks.—In the early stage of railway operations, the gauge, or width between the rails, excited a hot discussion, known as the 'battle of the gauges.' The 4 feet 8½ inches gauge, now prevalent in Great Britain, seems to have been adopted because it was the usual width of the wheels of ordinary wagons and carriages. This gauge was adopted on most of the earlier made railways; and, notwithstanding the keen contests of engineers, who were generally favourable to a 5 feet or 5 feet 3 inches gauge (Brunel contending for 7 feet), this original 4 feet 8½ inches gauge, measured from the inside of one rail to the inside of the other, became by degrees almost universally adopted in England, Scotland, and Wales, the Great Western and certain branches excepted, on which the gauge was regulated at 7 feet. Owing to inconvenience in communicating with other lines, and from other causes, the Great Western has found it advisable to conform to its neighbours, and has now (1877) relaid the greater part of its extensive system on the 4 feet 8½ inches scale. The Irish gauge is fixed at 5 feet 3 inches. The government of India fixed the gauge of all the railways in that country at 5 feet 6 inches. But a movement in an opposite direction has set in within the last few years, and the battle of the gauges is renewed. A horse tramway at Festiniog in Wales, constructed in 1832 for the conveyance of slates from a quarry, and laid with a 1 foot 11¾ inches gauge, was, in 1863, transformed into a locomotive railway, for passengers and goods, and was found to work with perfect safety and with remarkable economy. The success of this experiment has awakened the attention of many engineers to what they believe to be the needless extravagance of the standard gauge; and railways with gauges varying from 2 feet 6 inches to 3 feet 6 inches are now in operation in Norway, Sweden, Russia, Queensland, Peru, Chili, Brazil, Canada, and especially in the United States, where a vast mileage is built or in course of construction. The great argument for the narrower gauge is the obvious economy both in first cost and in working. It is calculated that, on an average, companies have to haul over their lines seven tons of dead-weight in order to carry one ton of goods; and in the case of passenger-carriages the excess is even greater. With the whole apparatus on a smaller scale, this waste is greatly reduced. Another advantage of the narrow gauge is, that much sharper curves may be adopted than are possible on the broader one, and thus the route may be chosen to much greater advantage. While it may be an open question whether the narrow gauge is adequate for a thickly peopled district, where 'express' trains may be indispensable, and where traffic may at times be exceptionally heavy, it is, without doubt, especially suitable for sparsely peopled districts and half-developed territories. Indeed, it affords the means of supplying the benefits of railway communication where otherwise they would be hopeless. After careful investigation, the Indian government of the late Lord Mayo decided to adopt the metre gauge, about 3 feet 3 inches, for the greater part of an extensive series—1500 miles—of state railways, and considerable progress has already been made in their construction. In Canada, there are several thousand miles of narrow-gauge railway.

Ballast.—This is the name given to the mass of broken stones, or dry gravel, on which the sleepers are placed, and which serves to keep them steady. The term *ballast* originated in the practice of using the gravel ballast emptied from the ships in the Tyne for the tram and railways in the neighbourhood of Newcastle.

Rails.—Rails are generally of malleable iron, but steel rails have been extensively adopted where there is a continuous heavy traffic, and are found to reduce considerably the cost of maintenance. Rails are made of various shape and weight. The most common form is the 'double-headed' rail, which is reversible. Another form, which was used on the Great Western for the broad-gauge line, is known as the 'bridge-rail;' and a form frequently used on the continent, and generally on narrow-gauge lines, has a flat base formed by a flange on each side of the vertical web. The two last descriptions do not require *chairs*, but are fastened directly to the sleepers by spikes. Rails are generally 21 or 24 feet long, and for light railways vary in weight from 20 to 45 lbs., and for heavy lines from 60 to 80 lbs. per lineal yard. Cross sleepers are laid at 2 feet 6 to 3 feet 6 inches apart, usually about 3 feet, and on these sleepers the *chairs* of cast-iron are fixed and held firmly down by iron spikes driven into the sleepers. The ends of the rails are now almost always joined together by two plates of malleable iron, called fish-plates, placed one on each side, and bolted together by four strong bolts passing through the rails. In the joining of the rails end to end, to make a smooth surface, great care is bestowed; perfect steadiness in the required line of direction is secured by means of wooden wedges, or *keys*, acting on the rails and the chairs.

Owing to the scarcity of native larch, which was preferred, sleepers have latterly been made of timber from the Baltic; they are sometimes *creosoted*, to render them durable, but generally they are found to split, and require renewal before rotting. A cast-iron sleeper, very much the shape of a pot lid, having the chair cast on the top, has been much used by English engineers on railways abroad.

Tunnels and Viaducts.—In designing railways, tunnels have been as far as possible avoided, owing to their costliness. They are made only when the excavations would be more than 60 feet in depth, or when land-proprietors force their adoption, in order to spare the amenity of grounds near a mansion. For this latter reason, some short tunnels are known to have cost railway companies as much as £50,000. Latterly, the execution of underground railways in the metropolis has offered examples of tunnelling more extensive than were previously

known in England, and at the same time popularised a method of subterranean transit almost as marvellous as anything in the way of viaducts. The Woodhead Tunnel is 3 miles 60 feet in length, and the Severn Tunnel is about 3 miles long. But all our tunnels have been cast into the shade by that through the Alps near Mont Cenis. The highest summit of the section immediately over this tunnel is 9527 feet, and the summit level of the tunnel, 4246 feet above sea-level. It was completed in 13 years, cost about £200 per lineal yard, the total length being 7·6 miles, and was opened on the 26th December 1870. The time occupied in passing through the tunnel by train is 25 minutes. The St Gothard Tunnel, begun in 1872, was pierced by February 1880. The length is 9·2 English miles; the cost by estimate was £2,000,000. The Arlberg Tunnel, begun in 1880, was pierced by the end of 1883. It is 6 miles long, and gives railway communication between the Austrian province of Vorarlberg and Innsbruck in the Tyrol. The work of tunnelling has been greatly expedited, and the cost much reduced, by the invention of rock-boring machines.

In January 1872, a joint-stock company was registered for making a tunnel near Dover to a point near Calais. The government, however, in 1883, declined to sanction this undertaking.

Viaducts are bridges, frequently of stone, and of handsome architecture, or now more commonly of malleable iron girders of various forms set in stone or iron piers. In the construction of viaducts, there is a growing boldness of conception, originating with the success of the famed railway viaducts across the Menai Strait, the river Tamar, and the St Lawrence. The Tay Bridge, of iron girders, across the estuary of the Tay near Dundee, 3450 yards (nearly 2 miles) long, was opened in 1878, but was partially destroyed by a violent storm at the end of 1879. Remarkable works are the great suspension East River Bridge to connect the cities of New York and Brooklyn, more than a mile long, the central opening having a span of nearly 1600 feet; and the St Louis Bridge, a magnificent bridge crossing the Mississippi by three arches of unequalled width, the centre span being 520 feet clear of masonry.

Cost of Permanent Way.—Owing to the obstructions offered by landowners and their excessive claims for amenity damages, and also to the opposition of rival companies, the cost of railways was at one time very much greater than it is at present. It is estimated that in Britain the amount paid for land-claims has averaged £8000 per mile constructed. The expenditure incurred in securing legislative authority to construct railways was likewise enormous. The parliamentary costs of the Brighton Railway averaged £4806 per mile; of the Manchester and Birmingham, £5190 per mile; and of the Blackwall, £14,414 per mile! The cost of carrying the Liverpool and Manchester line was £27,000. It has been shewn that the solicitor's bill for the South-eastern Railway contained 10,000 folios, and amounted to £240,000. At the end of 1876, the total average cost of all the railways in the kingdom was £37,000 per mile open, or about double that of any other country. These few facts, however, afford but a feeble idea of the reckless wastefulness of capital on railway undertakings; it is universally allowed that, under a better policy, not only a much better railway system might have been provided, but an immense saving of capital effected.

The cost of construction varies so much, that it is impossible to say definitely what would be the average cost nowadays; but in England a double line, including station-houses, signals, and all other fixed plant, would probably cost, under ordinary circumstances, from £20,000 to £24,000 per mile. Single lines are made at perhaps a fourth less, but nowhere in the United Kingdom have they been executed so economically as in Scotland. There, some single lines have cost for land and everything not more than about £5000 per mile—such economy, however, being greatly due to the fact, that the undertakings were promoted and watched over by bodies of land-proprietors deeply interested in restraining expenditure.

Maintenance of Way.—Every railway, great or small, is at a considerable expense in keeping the line in proper working order, for which purpose a staff of officials is required. Besides a general superintendent, there is an effective staff of 'plate-layers,' whose duty it is to watch over and repair the permanent way.

ROLLING STOCK.—Under this head are comprehended locomotives, carriages, and trucks for goods and minerals, the whole forming an important part of railway undertakings.

Locomotives.—Locomotives are of several kinds, varied in construction to suit the traffic for which they are designed. They may be classed as express, ordinary, passenger, goods, and tank engines. In the latter class the tender for fuel and water forms an extension of the locomotive, but for the most part the tender is detached, and only connected by couplings. Locomotives for ordinary traffic have generally six wheels. In the first two classes, where speed is the principal object, only two, or at most four of the six wheels are *driven*, and these are made of large diameter. There has been a continual tendency to increase the speed, and this has led to the increase of the size of the driving-wheels, which are in some cases 8 feet in diameter. All the wheels of locomotives for heavy traffic are coupled together, so as to utilise the entire weight for adhesion. The smaller class of locomotives have only four wheels. The present price of first-class locomotives—of the largest size in general use—including the tender, varies from £3000 to £4000. Locomotives are now made at Crewe almost entirely (except the tubular boiler) of Bessemer steel, lighter, stronger, and cheaper in the end than those of iron.

Carriages.—There are three distinct kinds of carriages to suit the several classes of passengers. Each first-class carriage consists of three or four distinct compartments; but in the other classes the backs of the seats are in many cases not carried to the roof, leaving the upper part of the carriage open fore and aft. At night the carriages are lighted with lamps; on the Metropolitan lines gas is sometimes used. Saloon-carriages are chiefly reserved for royalty. The first-class compartments are handsomely fitted up, and in winter are furnished with long-shaped tin vessels of hot water for the feet. Recently, some of the first-class comforts have been conceded to the other classes. The Midland Company have introduced large and luxurious sleeping-saloon carriages, by the Pullman Company of America. Other companies have done the same with saloon-

carriages constructed at their own works. Many efforts have been made to devise some simple and efficient contrivance by which passengers might, in cases of emergency, summon the guard, but no plan has as yet been adopted to any extent. The 'continuous brake' is an improvement and novelty which has already been successfully tried, and is likely to be soon generally applied. By its use trains can be stopped in a much shorter time and distance than under the present system, and thus the risk of accident is reduced; brakes are fitted to each carriage, and all are simultaneously applied to the wheels.

Wagons and Luggage Vans.—To accommodate its traffic, every railway must be provided with a large stock of trucks or wagons for carrying goods, minerals, cattle, timber, and other articles. Wagons are now very generally fitted with elastic buffers.

Traffic.—The traffic on railways is of two distinct kinds—passengers and goods; with the goods we include minerals, also timber and other bulky articles. The passenger and goods traffic are placed under separate managements. Usually, there are passenger-trains and goods-trains, but mixed trains are very common on branch lines. In most parts of the United Kingdom, railway passengers are of three classes—first, second, and third. Though, from the fares charged, first-class carriages possess an air of exclusiveness, they are universally recognised as an advantage, for the reason that by the comparatively high fares exacted for them, the companies are enabled to lower the charges for second and third class passengers.

On April 1, 1872, three English companies began to run third-class carriages with every train, the Midland Railway Company taking the lead; and their example has been followed by most of the principal companies. The gross receipts from third-class passengers in 1871 were equal to about eight-ninths of the gross receipts from first and second class passengers together. Within the last few years there has been an astonishing increase in third-class traffic. The excess of third-class passenger journeys in 1871 compared with 1870, reached the enormous figure of 34,544,421, or an increase of nearly 15½ per cent. on the traffic of 1870. The subsequent rapid increase in third-class traffic will be noticed further on, in connection with the returns of 1876.

On some lines, first-class compartments are set aside for ladies if they please to use them. Smoking is limited to certain compartments.

Tickets are sold at a wicket not earlier than a quarter of an hour before the starting of the train. The tickets, marked in consecutive numbers, are stamped with the date on delivery, and excepting 'return tickets,' will not answer for any other day. Return and season tickets are issued at lower rates.

The number of trains run daily depends on the pleasure of the directors. There are ordinary, mail, and express trains; of this last kind, two usually go each way daily, the fares generally higher than by the others. Some of these trains are run at very high speed, and with wonderful punctuality. On June 1, 1872, London was brought for the first time within 9½ hours of the Scotch metropolis by a train, started on the East Coast route, which, deducting stoppages, runs at an average speed of nearly 47 miles per hour. Ordinary fares are about 2*d.* per mile first class, 1½*d.* second class, and 1*d.* to 1¼*d.* third class; but on some lines the fares are considerably lower, and higher on a few others. According to one of the provisions of a general act, all companies must run one train daily each way, stopping at all stations, and at a rate of speed not less than 12 miles per hour, at a fare of a penny a mile. Workmen's trains are run on some lines at extremely low fares, at early morning hours.

All trains are accompanied by a 'guard,' who is responsible for their management while running. Considering the vast number of servants on some lines—the number on one line and its affiliated branches being 20,000, and the total on all lines probably 200,000—the general good conduct shewn is highly creditable.

According to English practice, passengers are allowed to find their way promiscuously to the proper carriages, the only check being a call by the guard to 'shew tickets' previous to starting. All passengers are expected to see their luggage labelled for the place of destination, and to point out what belongs to them on arrival. This is a loose practice, often remonstrated against, but it suits the temperament and self-relying habits of the people better than the restraints and formalities of the continental system. In some railway systems the carriages are so constructed that the guard can perambulate the train while in motion. In British railways, this is not the case. This privacy and seclusion, however, are thought to be attended with a disadvantage—namely, that passengers are unable to call for assistance of the guard in cases of threatened outrage by one of their number. To all the numerous devices suggested for summoning the guard, and, if need be, stopping the train, there is, unfortunately, the grave objection, that if passengers were enabled to call the guard at pleasure, they would frequently do so for no sufficient reason.

To enable companies to reckon easily with each other as regards intercommunication of traffic in passengers, goods, use of carriages, &c. an institution called the Clearing House has been established in London, to which tickets are transmitted for cross-reckoning and settlement. There is a similar establishment in Dublin.

The cost of working railways, including general expenditure, in the United Kingdom exceeds one-half of the returns from traffic, and this compares favourably with other countries. The remainder forms the divisible profit to pay—1st, the interest on debentures, stock, and loans; and 2d, the dividend to shareholders.

Lowness of fares can only be secured by a large and well-sustained traffic; and the main reason why fares are much higher than they seemingly might be, is the frequent insufficiency of the number of passengers compared with the accommodation provided for them. A striking exemplification of the possibility of conveying large numbers at very low fares is afforded in the case of 'excursion trains,' in which sometimes 1000 individuals are taken 50 or more miles and brought back the same day for two shillings or half-a-crown each.

Captain Tyler's Report, presented to the Board of Trade annually gives very copious official

statistics relating to the railways of the United Kingdom. The following are a few of the particulars for 1876:

Length and Cost of Lines.—Length open in England and Wales, 11,789 miles; in Scotland, 2721; in Ireland, 2148: total in United Kingdom, 16,658 miles. Share capital paid up, £466,794,056; debenture stock, £123,000,684; loans, £40,428,754: total capital raised, £630,223,494—equal to nearly £38,000 per mile finished and opened. The average interest yielded on the whole of the capital was at the rate of 4¼ per cent. per annum. Nearly £47,000,000 of the whole amount received no dividend or interest whatever; a small portion received as much as 12 per cent. The predominant or most general rate for ordinary shares was 6 per cent.; for guaranteed shares, 5 per cent.; for preference shares, 5 per cent.; for debenture stock, 4 per cent.; and for loans, 4 per cent.

Traffic Receipts.—Gross receipts from railway working, £58,982,753; working expenses, £32,198,196 (excluding receipts and working expenses of steamboats, canals, ports, and harbours belonging to railway companies); proportion of working expenses to gross receipts, 54·6 per cent. Receipts by passenger trains—first class, £4,725,506; second class, £3,842,592; third class and parliamentary, £12,985,829; season and periodical tickets, £1,151,248; mails, parcels, carriages, horses, dogs, and excess luggage, £3,009,060. Receipts by goods trains—minerals, £13,405,283; general merchandise, £18,630,480; live-stock, £1,204,548. Total gross receipts by trains of all kinds, £58,982,753; 44 per cent. earned by passenger trains, 56 per cent. by goods trains. The money paid by passengers per mile per annum was £284 first class, £231 second class, £779 third class and parliamentary, and £67 season tickets, &c.: total, £1361. Total number of passengers carried, 507,572,491.

Expenses, &c., of Working.—Total expenses per train mile, 36·88*d.*, against 60·06*d.* receipts per train mile by passenger trains, and 75·32*d.* by goods trains. This shews that every mile of railway in the United Kingdom earns on an average about 5*s.* by every passenger train, and 6*s.* 3*d.* by every goods train, or 6*s.* 8*d.* on an average of all kinds of trains—of which the working expenses absorb nearly 55 per cent.

Figures for 1881.—Total length of railways at work in the United Kingdom, 18,175; gross receipts, £66,557,442; working expenses, £34,602,616—being 52 per cent. of the receipts; net revenue, £31,954,826. The total quantity of minerals carried were 174,000,000 tons; of general merchandise, 70,000,000 tons. The companies received £15,192,000 for carrying minerals, £20,145,000 for general merchandise, and £1,096,000 for live stock. The earnings per train mile were for passenger trains, 4*s.* 3½*d.*; and for goods trains, 6*s.* 0½*d.*; the general average being 5*s.* 1¾*d.* The working expenses were lower than in any year since 1872; the companies having begun to reap the benefit of the great outlay on account of steel rails, now generally substituted for iron ones. Over £30,000,000 were distributed by the companies in dividends or interest. One small mineral line paid 16½ per cent. on capital; the North-Eastern paid 8 per cent. on its ordinary capital. About 350,000 persons are employed on the railways of the United Kingdom. The fastest running is made by the London, Chatham, and Dover Company, some of whose trains run (without stoppages) at 78 miles an hour.

Railway Accidents.—In the year 1876, 1245 persons were killed by railway accidents in the United Kingdom, and 4724 injured; considerably more than half the number were servants of the companies; 101 passengers were killed and 604 injured by their own fault. In 1881, 1096 persons were killed and 4564 injured; only 85 passengers being killed and 993 injured by causes beyond their own control. There were numerous cases of trains running over cattle which had strayed upon the lines.

Foreign Railways.—The first continental country that availed itself of railway locomotion was the small kingdom of Belgium, where a number of lines were constructed between 1834 and 1836. From Belgium railways spread to France, where they were laid down on a plan prescribed by the government, which offered special encouragement to capitalists. The government gave the land, made the bridges, and in many cases was at the entire expense of the permanent way; it relinquished the property on the footing of a lease, and frequently gave large subventions on the plan of receiving a share in the profits after a certain dividend had been paid. By one or other of these arrangements the state has secured a very general right of property in the existing lines. Latterly, there has been a disposition in companies to act on an independent footing. By means of subventions, as well as a species of guaranteed monopoly of traffic, the profits to shareholders in some French lines reach from 10 to 12 per cent. Within 99 years from 1852, a large proportion of the French railways will lapse into possession of the state. On one or other of the various plans of government helping companies, and preventing ruinous competition, nearly the whole railway system of continental Europe, Asia, and Africa is established; and in a large number of the foreign railway undertakings everywhere much British capital is invested. The principal continental railways, particularly in France and Belgium, are double lines, and under good management; but the rate of transit is generally slower than in England, and the formalities as to taking tickets and being allowed to enter the trains are found troublesome by travellers from the United Kingdom.

In Canada, Nova Scotia, and Australia, railways have been successfully established; but in no British dependency has the railway system been pushed forward with such activity or likelihood of advantage as in India. The undertakings have been materially assisted by government, by giving the land to the companies, by subventions in proportion to the actual outlay, and in some instances by guarantees of a minimum dividend of 5 per cent. to shareholders. About two-thirds of the lines now in course of construction will be government lines.

Railways in the United States date from 1830. Since that year the progress of railways has far outstripped that of Great Britain. All the American lines are constructed and worked by private companies, but in other respects they differ materially from similar undertakings in England. They

have been liberally aided by government in grants of land. The lines have generally no fences, and they go through populous towns along the open streets without restriction or fear of the consequences; the only care taken against accidents is for the driver to ring a bell, and it is usual to put up boards with the inscription: 'Look out for the locomotive when the bell rings.' Tickets are sold at the stations, at offices throughout a town, and by the guard, without fixing a date; the whole organisation and management being, in fact, on a loose footing, though perhaps well adapted to the raw condition of a large part of the country. The seats in the 'cars,' as they are termed, are arranged in rows, with a passage up the middle for the conductor, who, by means of a small platform at each end, can step from carriage to carriage, and perambulate the train at pleasure. The wheels being attached to a swivel or *bogie* framework, the cars can turn round corners with the ease and security of a gentleman's carriage; this being the most ingenious of the American mechanical arrangements.

The greatest works of late years have been the American trans-continental lines. The first, the Union and Central Pacific, was opened for through-traffic between New York and San Francisco, a distance of 3363 miles, in 1869. The journey can be made in 170 hours, including seven nights in succession in the cars, but passengers with through-tickets can get a 'lie-over' ticket to break the journey. The Southern Pacific from New Orleans to San Francisco was finished in 1882. A third great line, the Northern Pacific, was completed in 1883; and a fourth, the Canadian Pacific, was being constructed. A trans-continental line is also being carried out in South America. The Lima and Oroya line is one of the most gigantic undertakings of the time; it will cross the Andes at an elevation of 15,000 feet.

A railway was opened in Japan in 1872, and in 1880 there were over 60 miles open for traffic. A line of railway was opened in China in 1876, extending from Shanghai to Woosung; unhappily it was destroyed by order of the government in 1877. A curious mountain-line, the Righi Railway, opened in Switzerland in 1871, about 3¼ miles long, rises 3937 feet; the average gradient for the whole distance being 1 in 4·45. It crosses a viaduct on a gradient of 1 in 4. The line has a central rack into which toothed wheels, on the locomotive, gear.

Statistics of Railways in all Countries.—The British possessions in 1875 contained in the United Kingdom 16,658 miles of railway; India, 6461; Dominion of Canada, 4443; Australia and New Zealand, 2285; with small portions in other regions—making a total of 30,205 miles. Of foreign railways unconnected with the British possessions, the latest available statistics present the following figures: France, about 19,000 miles; Belgium, 2300; Holland, 1100; Denmark, 600; Sweden, 1100; Norway, 600; Russia, 12,000; Germany, 15,000; Switzerland, 900; Austro-Hungary, 14,000; Italy, 5000; Spain, 5000; Portugal, 1000; Roumania, 600; Turkey, 600. Beyond the limits of Europe are Egypt, 1000 miles; the United States of America, little less than 70,000 miles; Mexico, 400; Central America, 200; Peru, 600; Chili, 800; Brazil, 900; La Plata, 1000. The railways of the whole world, in the beginning of 1880, probably reached 200,000 miles, equal to eight times the circumference of the earth; besides large additional portions commenced, but not completed.

We give below the average fares charged to first-class passengers for a journey of 100 miles in the principal countries of Europe: In Belgium, 6*s.* 6*d.*; Italy, 10*s.* 6*d.*; Spain, 11*s.* 9*d.*; Prussia, Denmark, Austria, 13*s.*; France, 13*s.* 4*d.*; Norway, 13*s.* 4*d.*; Switzerland, 13*s.* 6*d.*; Holland, 14*s.*; Portugal, 14*s.* 2*d.*; Russia, 14*s.* 5*d.* In the United Kingdom it was 18*s.* 9*d.* some years ago; in 1877, about 17*s.* 3*d.* Second and third class shew the same results proportionally. Goods-rates present a still more striking contrast. For passengers and goods alike, Belgium is the cheapest country, the United Kingdom the dearest.

Victoria Railway Bridge, Montreal.

MARITIME CONVEYANCE.

IN the present article we propose, first, to say a few words as to the principles of naval architecture, to speak of practical shipbuilding in wood and iron, and to describe the different classes of ships. We shall give a short history of steam-propulsion, and some account of its present condition, with an account also of the present condition of our merchant navy; and, in conclusion, we shall glance at some points connected with navigation which may fairly come under the head of Maritime Conveyance.

Of the early history of ship-architecture little can be said of any importance. The buoyant property of water must have been early observed by mankind; and, beginning with rude skiffs and canoes, they would in time acquire sufficient skill and experience to build vessels of a larger size, and to guide them in the required direction by means of a rudder and sails. The cultivated nations of antiquity—Egyptians, Phœnicians, Carthaginians, and others—possessed ships for commerce and war, some of which were of large dimensions. Galleys, or vessels propelled by oars, continued in common use till the sixteenth century, and played a principal part in all sea-fights up to that time;* but of these early vessels, as well as of those now employed by half-civilised nations, it is unnecessary here to speak; we proceed rather to notice the construction and character of ships as they are made now that naval architecture has become a science.

SHIPS.

The naval architect and the shipbuilder stand in the same relation to each other in reference to ships as the architect and builder do in reference to buildings, the one designing, and the other executing. In most cases, however, the two professions are combined in one firm, if not in the same men. All ships have to possess certain qualities, the principal of which are buoyancy, stability, handiness, and speed; but it is not possible for any ship to possess at the same time the maximum of all these, as to some extent they neutralise each other. The skill of the naval architect is shewn in duly proportioning them to one another, ascertaining which are the more important in each particular case, and providing these without unduly impairing the others. In some vessels, it is essential that the greatest possible speed should be attained; while, as they are to work only in smooth water, their degree of stability (or freedom from excessive rolling, and tendency to right themselves when heeled over by a wave) is only secondary. In others, which have to weather long-continued storms in mid-ocean, speed may have to be sacrificed to attain greater steadiness. In sailing-vessels, where the means of propulsion is not under control of the crew as in steamers, handiness, the property of answering quickly to their helms and of readily performing various manœuvres (such as tacking) under all conditions of weather, is often the quality to which most attention has to be paid. Along with all these things, the ship has to be made so as to have the largest possible amount of cargo or passenger space consistent with the proper degree of buoyancy.

The degree in which a ship possesses the various qualities named depends chiefly upon her external form and dimensions, and about these we must, therefore, say a little. The hull or body of a ship is supposed to be divided into two parts, called fore and after body, the one in front of, and the other behind, the greatest breadth of the vessel; and the curves of the body are called its 'lines.' In a vessel required specially to carry large cargo in proportion to her size, the lines will be 'full;' and in one in which great speed has to be attained at the expense of cargo-room, they will be 'fine.' Whether full or fine, however, in every well-designed ship they must be 'fair'—that is, continuous, and without any sudden changes of direction or curvature. Next to the fairness of the lines, the most important point about the designing of a ship is the proper proportioning of the lengths of the fore and after bodies. Our knowledge in these matters is quite recent, and we owe it in great measure to Mr Scott Russell and the late Professor Rankine. These gentlemen investigated scientifically the causes of the resistance offered by water to a ship's motion, and arrived at conclusions which are extremely valuable to the naval architect, but mostly too abstruse to be given here. Every vessel in moving through water must raise at least two waves on the surface, and cause them to travel along with her. As long as these waves travel in a direction parallel to that in which the ship moves, no appreciable power is lost in keeping them in motion; but if they diverge obliquely from the ship's course, they continually absorb power which ought to be employed in propelling the ship. It was the object of Mr Scott Russell's researches to find out how a ship might be designed so that no power might be thrown away in producing these oblique waves. It is known that the length of a wave,* like the length of a pendulum, determines the velocity with which it will naturally move. Mr Russell has shewn that the length of the fore and after bodies of a ship should bear certain definite proportions to the lengths of waves which would naturally travel at a speed equal to the maximum speed which the ship is intended to attain. For every speed, therefore, there is a certain minimum length which the vessel must possess. It may often exceed this length with advantage, but cannot fall short of it without inducing a waste of

* The first *ship*, properly so called, in the English navy was the *Great Harry*, built in the reign of Henry VII.

* Or distance from crest to crest.

power which is sometimes enormous. As waste of power means waste of coal, and waste of coal loss of money, and as waste of power can only be prevented by building ships in accordance with the conclusions arrived at by scientific men, much more attention is paid to these conclusions than would have been the case had they not affected the purses of shipowners. The result is, that a great improvement in the design as well as the construction of vessels has taken place within the last few years, and no doubt will continue to take place for a long time to come.

TONNAGE.

In connection with ships, the word *tonnage* will be constantly met. It is used in so many different senses, that it may be well, before going further, to explain its meaning, which may be either displacement, burden, registered tonnage, or builder's measurement. The *displacement* of a vessel is simply the number of tons of water which she displaces, which is of course exactly equal to her own weight. The *load* and *light* displacements are respectively the displacements with and without cargo. *Burden* is the difference between the light and the load displacement, or the number of tons weight which the ship can carry, in addition to the weight of her hull, masts, &c. The burden includes the weight of the engines, boilers, and coals, so these must be subtracted in order to find the *nett* burden for cargo. Both displacement and burden are expressed in tons of actual weight—that is, of about 35 cubic feet each.* The *registered tonnage* of a vessel, however, is expressed in tons of 100 cubic feet, and is found by measuring the internal capacity of the ship, and dividing by 100. It is *gross* or *nett*, according as it includes or not the capacity of the space occupied by the propelling power. *Builder's measurement* does not express either the tonnage or capacity of the vessel; it is founded on a law of 1773, and is a purely arbitrary function of certain dimensions of the ship. Like 'nominal horse-power,' however, it is still retained by buyers and sellers in their transactions.

DESIGN AND BUILDING.

In commencing to design a ship, the naval architect generally has given him as data the nett burden of the vessel, her draught of water, and her intended speed. The first part he designs is generally the midship section; he then draws one of the principal water-lines (or horizontal sections), having previously determined the best proportion of length to breadth for this particular ship; and then proceeds to work out the form of the ship in detail on three small scale drawings, called the sheer-plan, half-breadth-plan, and body-plan. The first of these shews the vessel cut in two vertically from stem to stern, and shews all the water-lines by horizontal, and all the cross sections by vertical lines; the second is a horizontal section taken at the line of greatest breadth, and shews the true shape of all the water-lines; and the third shews the midship section, and the true shape of all the vertical sections. It is usual also to construct a small wooden model of the ship from these drawings, which shews the designer what his ship is going to look like better than the flat paper can do. This model is made of a number of horizontal layers of wood, and can be taken to pieces at will; and thus a section of the ship at almost any place can be obtained. From the model and drawings all the lines of the ship are drawn down full size with chalk on the floor of a room called the 'mould-loft;' and from these chalk drawings the workmen are guided in the actual construction of the vessel.

One of the most noteworthy changes in the design of ships which has recently taken place is the gradually increasing ratio between their length and breadth. It is not many years since shipbuilders shook their heads over a vessel eight beams in length, and prophesied all kinds of evil for her. Assumptions were made in connection with this subject as groundless as the assumption that because the best speed for a horse drawing a barge was 220 feet per minute, therefore that speed was also the best for the piston of a steam-engine; yet this was gravely assumed by experienced engineers. Messrs William Denny and Brothers of Dumbarton have prepared an interesting diagram, which want of space prevents our printing here, shewing the gradual increase in the proportionate length of vessels built by them since 1845. It shews at first a length of 6½ breadths, it is nearly stationary for some years at 7¾ breadths, but in 1871–72 it reaches nearly 9½ breadths. Vessels are, however, built of even greater length than this. In those of the White Star line especially, a length equal to 11 breadths has been used, and found in every way successful.

Perhaps few changes of similar magnitude have occurred in so short a time as the change from wood to iron as a material for constructing ships. At the present time, the material out of which ships have been constructed since the beginning of the world has been almost superseded in thirty or forty years by the substance which perhaps least of all would have been thought by the ancients suitable for such a purpose.* About wooden shipbuilding, therefore, we need not say much. Shipbuilding yards are always close to the water's edge, and the ships are built endways to the water, with the after-end, or stern, nearest to it. The keel, which is the lowest part of the vessel—which corresponds to the backbone of an animal, and from which the ribs or *timbers* spring—is made first, and laid on blocks so arranged as to give it a slight inclination down towards the water. The timbers are next set up, and the cross beams which support the deck, and the whole is finally covered with the planking from bow to stern. When it is necessary to bend a plank for any part of the vessel, it is heated by steam, and then forced into the required shape by screws and levers. The planks are fastened to the ribs by *treenails*, and the plan is followed of allowing a space or seam between each plank, which is filled up or calked with oakum, and the whole is smeared with pitch. In most cases, the whole of the surface below the water-line is sheathed with copper, which to a great extent prevents its becoming foul through the accumulation of weeds

* A ton of water measures about 35 cubic feet.

* A glance at the table which concludes this article will shew that at present the tonnage of the iron ships annually constructed in Great Britain is about nine times as great as that of the wooden vessels.

and barnacles on a long voyage. The materials most used in the construction of wooden ships are oak, pine, teak, and elm; they require to be sound, well seasoned, and dry.

In an iron ship, as in a wooden one, the keel is laid first. It is sometimes made in one thickness, of a heavy bar, and sometimes is made of two or three thicknesses of plate, riveted together. The ribs in an iron ship are called 'frames,' and are curved to the desired shape while in a red-hot condition. They are always made of angle iron (*a*, fig. 1), and are placed from 18 inches to 2 feet apart. To the frames are fastened at the bottom the *floors*, which are narrow plates running across the ship; and frequently additional stiffness is gained by running 'reverse' angle irons along the top of the floors. The horizontal beams which support the decks are made of such a section as is shewn at *b* or *c* (fig. 1). After the frames, floors, and beams are in place, the plating commences, each particular plate being of a size and shape exactly as settled by the model. The lowest plates of all are called the 'garboard strake,' and are usually riveted to the sides of the keel. The thickness of the plates gradually diminishes upwards, till the 'sheer strake'—the strake at the level of the main-deck—is reached, and this is always made very strong. The deck-beams are further secured by longitudinal and diagonal plates called 'stringers.' All the ironwork of a ship is fastened together by rivets. Holes are first punched in the plates and angle irons; these are then made exactly to overlap (see fig. 2), and a red-hot rivet inserted through them. A man, called a 'holder-up,' holds the head of the rivet forcibly in its place with an iron tool, while two riveters on the other side of the plate strike its end rapidly with their hammers, until it is all hammered down as at *a*. The contraction of the rivet when it cools causes it to hold the two plates still more tightly together. Iron ships are always divided into a number of compartments by transverse partitions, called 'bulkheads.' These partitions can easily be made water-tight, and afford great additional security to the vessel, as, in the event of a leak occurring, it will often be possible to confine the water to the space between two bulkheads, and so prevent the vessel sinking. They are also the cause of great additional transverse strength.

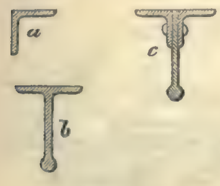


Fig. 1.

Fig. 2.

By the time the external plating of the ship is finished, and the beams and bulkheads all in their places, she is ready for launching, but much still remains to be done to her. In general, the greater part of the decks have to be laid, and the whole of the cabin-fittings to be put up; the rudder and steering-gear have to be fitted; the masts have to be set, and all the spars, sails, and rigging put up; and lastly the engines and boilers have to be placed and properly secured on the seatings provided for them. Of late, steel has come rapidly into favour as the material for building ships.

The decks are made of narrow pine planks laid side by side, with a little space between each, and calked with pitch and oakum exactly like the sides of wooden ships.

The rudder is an iron* apparatus placed at the stern of the ship, under the water-line, by means of which the vessel can be turned or steered to one side or the other. It is pivoted or hinged like a door, and by means of a hand-wheel placed on deck and connected with it by suitable gear, it can be moved to right or left (starboard or port). The action of the rudder on the water is such that the ship's head is compelled always to turn to the *same* side as that to which it is inclined.

The masts of a ship are carried right down through the decks, and rest on the top of the keel. They are securely fastened where they pass through the decks, and are further steadied above-board by the shrouds and rigging. In vessels possessing only two masts, the after-one is called the main-mast, and the other the foremast; in vessels with three masts, the after is called the mizzen, the middle the main, and the forward the foremast. In large ships, each mast is made in a number of lengths, the upper ones of which can be lowered at will. The pieces are called, in order going upwards, mainmast, maintop-mast, maintopgallant-mast, &c.; or foremast, foretop-mast, &c. as the case may be. The cross-pieces to which the sails are fastened are called *yards*; and the pole standing out at an angle from the stem of the vessel, the *bowsprit*. The yards and the bowsprit are called the *spars*, so that the expression 'masts and spars' includes the whole of the woodwork which has to do with the sails. The rigging which stays and strengthens the fixed portions of masts and spars is called standing-rigging; while the ropes used in working, shortening, and manœuvring the sails constitute the running-rigging. The latter always consists of strong, well-spun ropes, generally of hemp or manilla; but the former is now very often made of iron or steel wire twisted into strands.

The sails of a ship are sheets of canvas, either fastened or 'bent' to the yards (in which case they lie athwart-ship), or traversing on stay-ropes fore-and-aft, or bent to 'gaffs.'† Although the rapid progress of steam seems to be almost driving out large sailing-vessels, still it may be interesting and useful to describe the sails of a full-rigged ship, as fig. 3. Since the introduction of steam-power, vessels are not made to carry anything like such a press of canvas as is here mentioned, being no longer solely dependent on their sails for propulsion, and often very large steamers are merely schooner-rigged. Ships seldom or never have the whole of their sails set at one time, and in fig. 3 several of them are not seen; a glance at figs. 4 and 5 will, however, make the description intelligible. Beginning at the forward end, there are first three triangular sails—the flying jib, the jib, and the foretop-mast staysail, leading from the bowsprit ‡ to various points on the foremast. On

* Wooden in a wooden ship.

† Spars doing the same duty as yards, but lying in a fore-and-aft plane.

‡ The bowsprit is made in lengths like the masts, the outermost portions being called the jib-boom and the flying-jib-boom.

the foremast there are, or may be, five squaresails, each with its own yard, the foresail or forecourse, foretop-sail, foretopgallant, royal, and skysails. The

Fig. 3.

smaller and higher ones are only used in very light winds. All these sails can be turned at pleasure, so as to be presented to the wind at the proper angle, by means of braces attached to the end of their yards, and leading to the mainmast. The mainmast is furnished with a similar set of sails, somewhat larger; and the mizzenmast also with a set, though somewhat smaller. The mizzenmast, however, instead of a square 'course,' has a large fore-and-aft sail called a spanker or driver, hoisting up abaft the mast. Some ships have similar sails on the fore and main masts, which are found of great use in gales of wind, as a substitute for storm staysails; and most ships also carry light triangular staysails between the masts. Studdingsails spread beyond the squaresails (on each side) like wings, are found useful in going before a light breeze.

SAILING-VESSELS.

Sailing-vessels are of numerous sizes, shapes, and modes of rigging; these depending not merely on the particular trade for which they are intended, but often also on the taste or whim of their owners. By the aid of figs. 3, 4, 5, and 6, we may describe the principal varieties. Fig. 3, which we have already referred to in speaking of masts and sails, represents the largest kind, the only one which strictly should be called a 'ship.' It has three masts, with square sails on each, rigged in the manner already described. The full complement of sails, not including skysails or studdingsails, is about twenty-four—of these the engraving shews only thirteen set, or partially set—namely, the jib, the forecourse, topsail, topgallant, and royal; the mainsail, maintop, topgallant, and royal; and the spanker, mizzentop, topgallant, and royal.

A *barque* is a threemasted vessel like a ship, but with only fore-and-aft sails on the mizzenmast. It has generally also a fore-and-aft driver on the foremast, in addition to the forecourse.

Next beneath the class of ships is that of *brigs*. A brig (fig. 4) has only two masts, but these are both square-rigged like those of a ship. The aftermast is the larger of the two, and is called the mainmast, the other being the foremast. As in the barque, the foremast of a brig has generally a fore-and-aft sail, called a trysail. A *brigantine* has the bowsprit and foremast of a brig, and the

Fig. 4.

mainmast of a schooner, and so combines to some extent the advantages of both square and fore-and-aft rig.

With brigs and brigantines square rigging terminates, and we come to classes of vessels in which the rigging is of a different character. At the head of these stands the *schooner*, a vessel sometimes with three, but generally with two masts. The rigging of schooners varies very much, but fig. 5 shews the most common type. The

Fig. 5.

masts are generally called main and fore, and the names of the sails will easily be made out from the preceding remarks. The maintop-sail is of a peculiar shape, and is called a gaff. The mainsail has yards both at top and bottom, the lower one being called a *boom*.

The sloop or smack (called in the navy a *cutter*) has only one mast, and has an extremely large mainsail. Its principal sails are shewn in fig. 6, but in addition to these it has a gafftop-sail, and several jibs to suit different states of the wind. Yachts, which are generally built for the purpose of attaining the greatest possible speed, are always fore-and-aft rigged, with either one or two masts, like a sloop or schooner.

All the preceding classes of vessels possess

decks. Small open vessels, not possessing decks, belong to the class of *boats*, of which there are many varieties. They are divided into two leading classes, according to their mode of construction. When made flush on the outside, and in other respects like a miniature ship, they are called *carvel-built;* and to this class belong long-boats, pinnaces, yawls, &c. When made with the

Fig. 6.

lower edge of each plank overlapping the upper edge of the plank below it, they are called *clinker-built;* and to this class belong gigs, jolly-boats, dingies. *Diagonal-built* boats have a double skin, flush on the outside. Clinker-built boats possess the greatest strength in proportion to their weight, and are therefore most generally in use. The Merchant Shipping Act regulates the minimum amount of boat accommodation which passenger-ships are compelled to carry, &c. The special class of life-boats will be found treated of at the end of this number.

Ships always carry from four to six or seven anchors. In large vessels, two *bower*-anchors, for ordinary use, are kept on deck, while two exactly similar are carried in case of accident; a *stream*-anchor is used for riding in sheltered places; and a *kedge* for warping the ship along a river's channel. According to the report made by a committee of investigation in 1852, the two anchors which were the best in every respect were Rodger's and Trotman's. Of these, the former was forged in one piece (excepting the cross-bar or *stock*), while the latter (shewn in fig. 7) has the

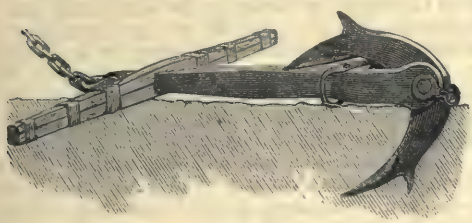


Fig. 7.—Trotman's Patent Anchor.

arms separate from the shank. Loose arms have several advantages, among which are—that the fluke which is not acting is not liable, from its position, to foul the cable; that the difficulty of obtaining a sound forging at the junction of the arms and shank is obviated; and that the strain is more advantageously distributed. The use of the *stock* or cross-piece, which is more often made of iron than of wood as in the engraving, and which always lies in a plane at right angles to that of the arms, is to make the anchor *cant* on reaching the ground, so that one or other of the arms is sure to take hold.

In every class of merchant-vessels the prime object is to carry as large a quantity of goods as possible, and therefore comparatively little space is set apart for the accommodation of the captain or his crew. If the cargo be light, or if the vessel be returning empty from her port of delivery, *ballast* is put in her hold, in order to give her the immersion necessary for proper stability. Recent researches have shewn how closely connected the motions of a ship are with her degree of immersion in the water as well as with her external form, and it is now possible to calculate, with a near approximation to accuracy, the maximum angle to which any ship, under given conditions of draught, &c. will lie over, or *heel*, without tendency to upset. If her weights are wrongly placed, if she is, for instance, top-heavy, owing to improper deck-load, the naval architect can tell beforehand that if, in rough weather, her heeling-over reaches a certain angle, she will turn over, and go to the bottom. In the navy, iron is used for ballast; in merchant-vessels, often sand, shingle, or any other heavy and inexpensive material. No one who has ever sailed up the Tyne to Newcastle can fail to have been struck by the huge mounds of earth which line its banks, and which often reach a height greater than that of a ship's mast. The immense export trade in coal from the Tyne so greatly exceeds its imports, that the colliers in general return without cargo, and therefore 'in ballast;' and these mounds are simply heaps of ballast taken out of the ships, and placed, with much labour and cost, in their present position. A much simpler plan is, however, now adopted by all the colliers: tanks are formed along the bottom of the ship; these are filled, when the cargo has been discharged, with water; and this water forms the ballast. This plan has many advantages. The water can be let in without any trouble, and can be pumped out with very little trouble, and at the same time as the vessel is being loaded; while ordinary ballast has to be hoisted in and out; and as it occupies the same space as the cargo, those operations cannot be carried on at the same time as the unloading or loading of the vessel. The water-ballast also, being confined in tanks, is not liable to shift with the motion of the ship as other ballast may, and so prove a source of danger. It has the disadvantage that the tanks permanently lessen the cargo-space (although even this is not always the case), but this is far more than counterbalanced by the other considerations.

LLOYD'S, &C.

In order that a ship may be insured by the underwriters, it has to be inspected and surveyed by one of Lloyd's surveyors. According to the reports of their surveyors the committee of Lloyd's registry classify the vessel, affixing to its name a letter, which is intended to be as nearly as possible a correct indication of its real and intrinsic qualities. For wooden vessels, these letters (in the order of excellence) are A (in black or red), Æ, E, and I; for iron ships or steamers, they are

A, A, and A. Numbers put before these letters indicate the number of years for which they are to hold the grade indicated by the letter; and numbers (1 or 2) put after the letters refer to the completeness of their general equipment. Thus, 12 A1 denotes a wooden vessel of the highest class for twelve years, fully and perfectly equipped. If a ship has been built under the special superintendence of one of Lloyd's surveyors, it has, in addition to the above letter, a star attached to its name. Lloyd's committee publish an elaborate set of rules and tables, giving the minimum dimensions and thicknesses of which all the principal parts of a vessel must be made in order that it may be classed by them. They assign also to each class or size a certain minimum number and weight of anchors, length and size of cables, &c.; and in every respect do all they can to insure safe and strong work. It is not many years since ships were classified at Lloyd's with reference solely to their age and the place where they were built. Thus, two ships launched about the same time on the Thames or the Wear were enrolled together in the *highest* class in the register, and stood there for a certain number of years, no matter how different they might originally have been, or might afterwards become. Such a system was so manifestly preposterous, that it is only remarkable that it ever existed at all, and the present elaborate rules and periodical surveys are undoubtedly a very great improvement on it. There are not wanting those, however, who say—and with a certain amount of truth—that, in the present state of shipbuilding and naval architecture, Lloyd's elaborate regulations operate to insure uniform mediocrity, and to discourage invention and originality.

STEAM-NAVIGATION.

It would be impossible within the limits of this article to give a continuous history of the growth and progress of our merchant steam-fleet; but it may be both interesting and useful to give a sketch of the early history and present condition of the principal of those great companies whose steamers carry British trade to every part of the globe, as well as of the early history of steam-propulsion.

To Scotland is due the honour of having given the real start to steam-navigation, although America was the first to prove the commercial advantage of the system. Mr Patrick Miller, an Edinburgh banker, who had a country residence at Dalswinton, in Dumfriesshire, after much speculation on the possibility of navigating a vessel without oars or sails, prepared, in 1787, a small triple boat, having rotary paddles in the two interspaces, driven by a crank worked by four men. Mr Taylor, tutor to Mr Miller's sons, suggested a trial of steam instead of manual power; and it was agreed that a new boat should be made, and fitted with a steam-engine, under Taylor's superintendence, by Symington, an ingenious mechanic. One paddle only was used in this case, working in the interspace of a twin-boat. The first steam-voyage was made on a small lake at Dalswinton, on the 14th October 1788. The cylinder of the engine was 4 inches diameter, and the speed attained 5 miles. Another steamboat, 60 feet long, was made for Mr Miller, and was propelled on Christmas Day, 1789, at the rate of 7 miles an hour, on the Forth and Clyde Canal. It was, however, abandoned as a commercial speculation, through fear that the undulation produced by it would injure the canal banks. Several years afterwards, Symington took out a patent, under which a steamboat, called the *Charlotte Dundas*, was tried for a time on the same canal in 1803. It had a cylinder 22 inches diameter, and 4 feet stroke, and had one wheel working in a well-hole near the stern. Henry Bell, a clever Glasgow mechanic, who had witnessed the experiments of 1789, took up the subject at a later date, after Symington had abandoned it. It was not, however, until 1811 that he placed a small steamer in operation on the Clyde. This was the *Comet*, a vessel of 25 tons burden, 40 feet long, and 10′ 6″ beam, and with engines of 3 horse-power. Small as it was, it steamed down the Clyde against a head-wind at 5 miles an hour. Meanwhile, Robert Fulton, an American of great ingenuity and energy, taking up an unsuccessful patent of Livingston's (with whom he worked), adding to it various details given to him by Bell concerning Miller and Symington's twin-boat, and supplying the rest from the resources of his own mind, placed a steamboat, called the *Clermont*, of 160 tons burden, on the Hudson river in 1807. It steamed 110 miles in 24 hours. The *Clermont's* engines, and those of at least two succeeding boats, were made in this country by Boulton and Watt. This is not the place to discuss the relative merits of Miller, Taylor, Symington, Bell, and Fulton as inventors; it is sufficient to say that the present generation owes a debt to them all.

Thenceforward the progress of steam-navigation was steady and rapid. The first steamer on the Thames was the *Margery*, 70 tons burden, and 14 horse-power, which ran between London and Gravesend in 1816: it was probably built in Glasgow about 1813. In June 1815, a small Clyde-built steamer (the name of which it is not easy to discover) arrived in the Mersey, and plied on that river, carrying the passenger traffic between Runcorn and Liverpool.

The Clyde, however, has been more associated with the growth of steam-navigation than any other river. After various minor trials between 1811 and 1818, Mr David Napier sent a steamer from Greenock to Belfast in the last-named year; it was the *Rob Roy* (90 tons, and 30 horse-power) which thus had the honour of being the first vessel to steam across a sea. He next planned the *Talbot*, to run between Holyhead and Dublin; and soon afterwards he established a line of steam-ships between Glasgow and Liverpool.

In America, the size and importance of the rivers caused that country to take the lead it has ever since maintained in *river*-steaming. About 1813, Mr Stevens made a steam-voyage from New York to the Delaware, along the Atlantic seaboard; and in 1819 the *Savannah* crossed the ocean from New York to Liverpool; but as she was chiefly propelled by her sails, this cannot be called a steam-voyage. The first *bona-fide* steam-voyages across the Atlantic were made by the *Sirius* and the *Great Western* in April 1838, the one in eighteen days, using sails part of the time, and the other in fifteen days.

For nearly fifty years after the successful application of steam to marine propulsion, the paddle-wheel continued to be the sole means of propulsion used. Attempts were made by Mr Stevens in America, by Mr Woodcroft, and others, to use a modification of the Archimedean screw, but without much practical success. Even during the eighteenth century, numerous writers had pointed out how a screw might be used to propel a vessel. The credit of practically introducing the screw-propeller, however, belongs to Mr F. P. Smith. This gentleman was not an engineer, and in no sense can be called the *inventor* of the screw-propeller, but he had great perseverance, and was backed up by sufficient capital to enable him to bring his labours to a successful issue. In 1837, he and Captain Ericsson made many successful experiments; but it was not till 1840, after the marked success of the *Archimedes* (232 feet long, and 80 horse-power), that government was at last induced to take up the matter. The first government vessel fitted with a screw was the *Rattler*, and from the experiments made with her was gained much of the information which has enabled shipbuilders and engineers to bring screw-propulsion to its present state of perfection. From an engineering point of view, screw-propellers are in all respects superior to paddles, but they have the one defect, that they cause a more uncomfortable motion of the ship—a disadvantage as regards the carrying of passengers. This, however, has not proved of sufficient importance to prevent their taking almost entirely the place of paddles.

The two largest British steam-ship companies are the Cunard Steam-ship Company, and the Peninsular and Oriental Steam-navigation Company. These two great enterprises were started in the same year, 1840—the one to trade to the West, and the other to the East—and they have continued to grow apace and abreast ever since that time. At present, the gross registered tonnage of the Cunard Company is about 90,000; that of the latter is over 150,000 tons.

We may take the Cunard line first, as its first voyage was made two years previous to that of the P. & O. Company, although their incorporation took place in the same year. In 1838, government made known its intention of establishing a line of mail-steamers between England and Halifax, and threw the contract for building and working the vessels open to competition. The contract was eventually obtained by the late Sir Samuel (then Mr) Cunard, Mr George Burns of Glasgow, and the late Mr David M'Iver. They started four steamers, the first (the *Britannia*) leaving Liverpool on the 4th of July 1840, and reaching Boston in 14 days 8 hours, bringing news one month later than had been brought by the immediately preceding vessel. There were great and well-founded rejoicings in Boston, banquets and firing of guns; and Mr Cunard, who was in the *Britannia*, is said to have received 1800 invitations to dinner in 24 hours! The Company, which started with four steamers, now possesses between 40 and 50.* Their paddle-steamers *Scotia* and *Persia* (the former 3871 tons) were for long considered unrivalled; but lately, screw-steamers of even larger dimensions have been added to the fleet; of these, the *Bothnia* and *Scythia* are each 4400 tons gross register; the *Gallia*, launched in 1878, is 5000 tons and has done the passage from New York to Queenstown in 7 days 21 hours. The *Arizona* did the same voyage in 7 days 8 hours.* The *Russia's* passage in 8 days 28 minutes was till then the fastest passage; the return voyage from Queenstown to New York being done in 8 days 6 hours and 56 minutes. The Cunard Company run weekly steamers to New York, Boston (these carry the mails), the Mediterranean, and Havre. They have also established steamers between Liverpool and Glasgow tri-weekly, between Glasgow and Belfast daily, with the mails; and between Glasgow and Londonderry.

* Ocean-going steamers only; not including steam-tenders, &c.

The Peninsular and Oriental Steam-navigation Company was incorporated in the year 1840, and has since that time, in spite of opposition and competition, kept its place as the carrier of our Eastern mails, and forms the principal means of communication with our Indian Empire, China, and Japan. Before its establishment, letters took from three weeks to a month to reach Alexandria from Southampton. Their first vessel, the *Hindostan*, left Southampton in September 1842, to open the line by plying between Calcutta, Madras, Ceylon, and Suez. The Peninsular and Oriental Company have, like the Cunard Company, steadily increased their fleet in size and efficiency, and they have at the same time been able frequently to reduce their fares and the cost of conveying mails. The latest mail contract made between the company and the government came into operation on Feb. 1, 1880: it lasts till Jan. 31, 1888. According to its provisions, the annual subsidy for carrying the mails is fixed at £370,000, or £50,000 a year less than the previous contract. The Company's steamers take in (besides the Mediterranean and Indian Service) Singapore, the Chinese ports, and Yokohama; and in the south, Melbourne and Sydney; the voyages from Southampton to Yokohama and Sydney being respectively 11,264 and 11,623 miles in length. The mere statement of these figures does not give any adequate idea of the difficulties which are entailed in dealing with such enormous distances. The service must be so arranged that mails leaving places so far apart as Yokohama, Calcutta, and Sydney on their appointed days must yet all reach Point de Galle together, in order that they may be forwarded to Suez. The steamers are thus at the same time in different quarters of the globe, subject to variations of wind and weather which cannot be foreseen, and (once they have left port) entirely without means of communication with their destination, or, indeed, often with land of any kind. Under these circumstances, the wonder is, not that irregularities occasionally occur, but that we should have got so accustomed to the punctual delivery of letters from the other end of the world, that we wonder what has happened if they are not on our tables at breakfast-time on the usual day, and would think something very unusual had happened if they were two days late.

The 'Anchor' line of Transatlantic, Peninsular, Mediterranean, and Oriental Steam-packet Ships was established in 1854. It has more than quadrupled its fleet since the last edition of this work appeared—that is, since 1858—and now possesses more than 30 steamers at work, representing

* *Mean* time in both cases.

a tonnage of 70,674, and 30,860 horse-power indicated. The Royal Mail steamers of the Transatlantic section, carrying the Scotch and North of Ireland mails between Glasgow, Moville, and Newport, usually accomplish the voyage in about 9 days.

The navigation of the St Lawrence presents unusual difficulties to the sailor; it is frozen in winter, and floating ice in spring chokes it up, and is a source of danger to ships far out into the gulf into which it empties itself. Besides this, dense fogs occur, especially during the melting of the ice, and bewilder the most skilful mariner. The importance of regular steam-communication with our Canadian colonies was, however, too great to allow any difficulties to stand in its way, and in 1856, Messrs Allan entered into a contract with the Canadian government to run mail-steamers between Liverpool and Quebec in summer, and Liverpool and Portland in winter. The service is carried on under the designation of the 'Montreal Ocean Steam-ship Company,' which is more commonly known as the Allan line. The average time taken on the voyage between Liverpool and Quebec is a little over ten days, the mean speed being about 10·9 knots per hour; one of the fastest runs made is that of the *Sardinian* in June 1879, between Moville, Ireland, and Quebec, in 6 days 23 hours and 30 minutes. The Allan line has now extensive connections with other parts of the American continent, having services to Halifax, Baltimore, St John's (Newfoundland), and the River Plate. Its steamers, like those of the other Atlantic companies, are continually growing in number and size, and all the most recent improvements for insuring safety and economy have been added to their machinery.

Three other lines of Transatlantic steamers claim a few words here: the Inman line, the National Steam-ship Company, and the White Star line. The full designation of the first of these is the 'Inman Steam-ship Company, Limited.' It is remarkable as the first ocean steam-ship company which unreservedly adopted the screw as a propeller instead of paddle-wheels, and also as the first to carry the emigrant by steam. Its steamers have made several very quick voyages across the Atlantic. The *City of Paris* was especially selected to convey H.R.H. the Duke of Connaught to Halifax, N.S., and accomplished the passage between Queenstown and that port, a distance of 2236 knots, in 6 days 19 hours, or 14 knots per hour; and the *City of Berlin* did the return journey from New York, a distance of 2850 knots, in 7 days 15 hours, or rather more than 15½ knots per hour. This is 9½ hours less than the time of the *Russia* on the voyage already mentioned. The *City of Richmond* has also made a very rapid run to the westward; leaving Queenstown on the 16th July, she arrived at New York on the 24th July. Mean time 8 days, or 15 knots per hour. The steamer *City of Berlin*, constructed on the Clyde, is 5500 tons.

The 'National Steamship Company' was formed in 1863. Its steamers are remarkable for their very great size, which reduces the sickness-producing motion at sea, and also enables ample height to be allowed between decks, and is favourable to proper ventilation. The *Egypt* measures 454 feet in length, 44 feet beam, 4670 tons gross register, and 600 horse-power nominal. The steamer *America* of this line, in 1884, performed the voyage from New York to Queenstown in 6 days, 14 hours, and 18 min. The next fastest passage is that of the *Oregon*, of the 'Guion' line, which only took 2½ hours more for the same voyage.

The 'White Star' line of steamers sailing between Liverpool and New York, are all of very large size and power, and have maintained from the first an exceptionally high average speed. The *Germanic's* passage in 7 days 11 hours 37 minutes mean time, or at a rate of speed equivalent to 16 knots per hour, in 1877, was till then the shortest on record. The two shortest passages previously were those of her sister ship the *Britannic*, 7 days 13 hours 11 minutes outwards (or about the rate of 15¾ knots per hour); and 7 days 12 hours 41 minutes homewards (or almost 16 knots per hour). All the steamers have compound engines of the most modern construction, so that this Company may be said to be doing for this class of engine what the Inman line did for the screw-propeller. The vessels of the White Star line are remarkable for their very great proportionate length, to which we have already alluded, and also for having their saloons, state-rooms, &c., placed amidships. These innovations have been largely adopted by other companies in vessels recently built.

The *Orient*, of 5400 tons register, built in Glasgow for the 'Orient Steam Navigation Company,' is one of the largest and finest steamers of the kind ever constructed. In 1879, she accomplished her first run to Australia in 37 days. The 'Union Steam-ship Company' in 1879 possessed a fleet of 14 splendid ships; for many years this company had the conveyance of the South African mails. The well-equipped South African mail service of Donald Currie & Co. proved of immense importance to the government during the progress of the Zulu war of 1879.

The West India and Pacific Steam-ship Company, and the Royal Mail Steam-packet Company, are the principal British lines to the West Indies and South America—the former from Liverpool, and the latter from Southampton.

The companies we have been speaking of have mostly the carrying of mails and passengers for their first object; but there are numerous private firms possessing fleets of their own in which the carrying of passengers is merely secondary, the transmission of goods being their chief object. Of these fleets—for their size often entitles them to that name—some consist of sailing-vessels entirely, while others are wholly or partly composed of vessels possessing auxiliary steam-power. The opening of the Suez Canal has given a new impetus to this trade, and many steamers have recently been built with a special view to carrying goods through the canal to the East. Our space will not permit us to say anything in detail about these vessels, but it may be interesting just to give the duration of the voyages on some of the principal routes:

Sailing-vessels—Melbourne, 70 to 80 days; New Zealand, 90; Valparaiso, 90; West Indies, 30 to 50; Hong-kong, 95; Shanghai, 100; Yokohama, 120; Tientsin, 145 days.

Vessels possessing auxiliary steam-power—Melbourne, 54 to 58 days; Bombay, 28 to 32; Calcutta, 37 to 41; Hong-kong, 48; Shanghai, 54; Japan, 60 to 62 days.

Although she has disappointed all the expectations of her promoters, and proved a gigantic failure as far as the original shareholders are concerned, we cannot conclude this notice of steam-navigation without mentioning the *Great Eastern*, the largest vessel ever constructed. She was intended to carry coals enough for a journey to Australia and back, to attain a speed of 20 miles an hour (16 knots), and, in fact, to be the commencement of a new era in the history of ocean-steaming. She was built at Millwall by Mr Scott Russell, from the designs of Mr Brunel. Her principal dimensions are: length between perpendiculars, 680 feet; length over all, 692 feet; and breadth, 83 feet. She is propelled both by paddles and screw. She failed altogether commercially at the outset; and an attempt to run her between New York and France during the great Paris Exhibition failed also. She was for many years successfully engaged in laying submarine telegraph cables, but latterly she was sent to Gibraltar to take up her position there as a coal hulk.

PROPULSION.

We now come to the consideration of the means of propulsion used in ships. Of the ancient method of propulsion by oars, it is unnecessary here to speak; and the sails used when the wind is the propelling power have already been described. It only remains, therefore, to speak of propulsion by steam. Two methods only of using the steam-engine to propel vessels have ever come into practical use—namely, the paddle-wheel and the screw-propeller. The former, being the older, claims our first attention. A paddle-wheel was used in the little boat of Mr Miller's which we have already spoken of; and wheels were also used in the *Comet* and in all the earlier steam-boats. Paddle-wheels are placed about the centre of the ship's length, on an axis or shaft running athwartships. The paddles or floats are made of some hard wood, and are placed radially on the wheel, and fastened securely to wrought-iron framework. The diameter of the wheel and the height of the shaft are so arranged that at the ordinary draught of the ship the upper edge of the lowest paddle-board is a little below the surface of the water, while at the lightest draught the board is just immersed. To obviate some of the disadvantages of fixed paddle floats, they have been made movable in what are called *feathering* paddle-wheels. These were very largely used at one time, in spite of their complexity, but are now almost entirely superseded by the screw-propeller. The engines used in paddle-steamers were almost invariably either oscillating or side-lever engines. Both kinds will be found described in the article STEAM-ENGINE, and it is therefore unnecessary to describe them here. The former had the merit of simplicity, but was very ill adapted to be used with the high pressures of steam now considered necessary for economy; nor could the compound system be easily applied to it. The latter type was exceedingly complicated, heavy, and expensive, and indeed was to a great extent superseded even before the paddle-wheel itself gave place to the screw. Paddle-wheels as a means of propulsion possessed many grave objections, and in ships of war they would have been almost useless: as they could not have been rendered invulnerable, or even fairly protected, they would simply have afforded a good target to the enemy, and when disabled, would have been a great hindrance to the motion of the ship under sail. In rough weather too, when the vessel was rolling much, one wheel would frequently be lifted entirely out of the water, while the other was deeply immersed in it. The strain thrown on the shaft in this way was enormous, and the danger of breakage very great. Fig. 8

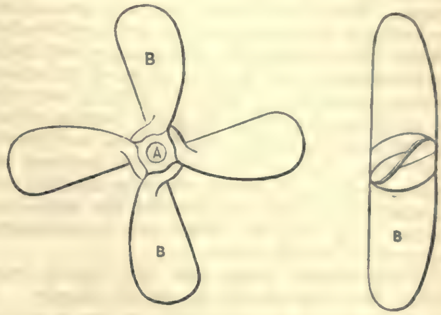


Fig. 8.

is an illustration of a screw-propeller of the ordinary form. It will be seen that it consists of small portions of four spirals, or screw threads, wound round the shaft A. At first, a whole spiral, or even a double spiral, was used, but experiments proved this to be unnecessary, and even injurious. Each of the arms, B, is called a *blade*. The action of the propeller in the water may be popularly compared (although this is not scientifically correct) to the action of an ordinary screw-nail in a piece of wood—the water remaining, as it were, stationary, while the screw continually bores its way through it. The number of blades given to a screw varies. When it is only used as an auxiliary to sails, and is taken out of the water (for the sake of avoiding useless resistance) whenever it is not used, it is made with two blades only.* A two-bladed screw, however, causes a great deal of jar and vibration in the stern of the ship, besides being not so efficient a propeller as one with a larger number of blades. It is, therefore, never used except where rendered necessary by such a reason as is given above. Some engineers make three-bladed screws, but there seems no reason why three should be chosen in preference to four, a number which possesses several advantages. The screw is always placed in an opening made in the stern of the ship just forward of the rudder and stern-post. It revolves on a shaft which lies along the ship horizontally, or nearly so. The diameter of the propeller must be such as to allow its upper edge to be fully immersed at the ordinary draught of the ship. Screw-propulsion is, therefore, not applicable to large steamers which have to work in very shallow water; while paddle-wheels of almost any size can be used with a draught of only two or three feet, as only such a small portion of their diameter has to be immersed. In many cases of light-

* The blades of auxiliary screws are often made so as to 'feather' or turn round till they lie nearly in the plane of the keel, for the same purpose that the whole screw is sometimes made to lift out of the water—namely, to prevent their acting as hindrances to the vessel's motion when she is under sail only.

draught steamers, where a propeller of the requisite size would only have been partially immersed, and where, for some reasons, paddle-wheels were inadmissible or undesirable, vessels have been fitted with two screws, each, of course, being proportionately less in diameter than a single one would have been to exert the same power. In these cases one propeller is placed on each side of the ship, under the quarter—that is, very nearly abreast of the place for the single screw. Steamers fitted in this way are called double or twin-screw vessels. They are always fitted with two entirely separate sets of engines, one to each screw-shaft, and they thus possess the advantage—very useful to war-steamers, and in some cases of impending collision, useful to any steamer—that by reversing one of the engines while the other is going ahead, the vessel can be turned round almost as if pivoted on her own centre. The additional expense and trouble, however, of having engines, shafting, and propellers all in duplicate, prevent the twin-screw system being adopted under any circumstances except those named above.

Screw-propeller shafts run very much more quickly than the shafts of paddle-wheels. At first, however, it was attempted to use in screw-steamers engines the same as those used for driving paddle-wheels, making up for the difference of speed by using toothed gearing between the screw and engine shafts. Such useless complication was soon found to be wasteful, and engines were made to work the screw-shaft direct, just as they had previously worked the paddle-shaft direct; so that each revolution of the shaft should correspond to a double stroke of the piston. For an exposition of the principles and construction of the steam-engine, we must refer to No. 27; but in this place we must give a short description of the type of engine now almost universally used —although modified in various ways by various makers—in merchant steamers of moderate size. Figs. 9 and 10 shew a direct-acting, surface-condensing, compound screw-engine. It is called direct acting, because the motion of the piston is transmitted to the crank direct, without the intervention of anything but a connecting rod; surface condensing, because the steam is condensed on the surface of a number of small tubes, kept cool by a current of water inside them; and compound, because the steam is admitted direct from the boiler to only one cylinder, and to the other and larger cylinder only after it has done its work in the first. The objects and advantages of surface-condensation and the compound principle have been fully entered into in the article above referred to, with which we must presume

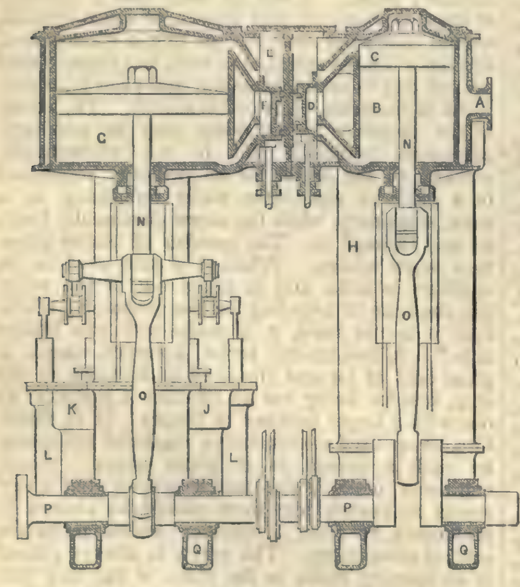


Fig. 9.

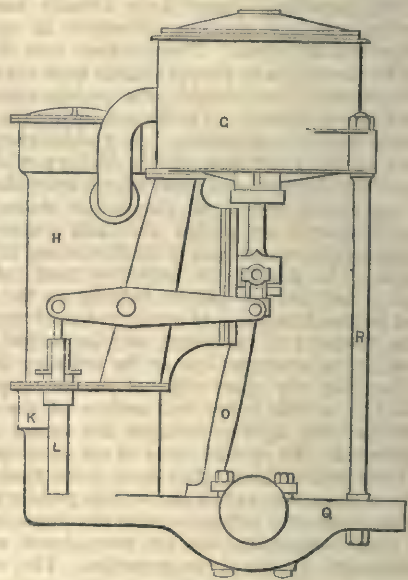


Fig. 10.

the reader of this to be familiar. Fig. 9 is a vertical section of the engine in the plane of the screw-shaft; and fig. 10 an end-view of the same engine, looking aft.

A is the main steam-pipe from the boilers; B, the smaller or high-pressure cylinder, with its piston, C, in which the steam commences its work. D is a slide-valve, regulating the distribution of the steam to B. When the steam has done its work in B, it is allowed by the valve to pass into a receiver, E, and thence another slide-valve, F, admits it to the low-pressure cylinder, G. It is here expanded until its pressure is much less than that of the atmosphere, and then allowed to pass into the surface-condenser, H. This condenser is full of small tubes, through which a constant current of cold sea-water is kept flowing by means of a circulating pump, J. The steam from G coming in contact with the outer surface of these tubes, is condensed; and an air-pump, K, draws it off in the form of distilled water along with the air, which, from one cause and another, may have found its way into the engine. The air is simply discharged into the atmosphere, while the water is delivered into the boilers again by the feed-pump, L. The same water is thus continually

used over and over again, the small losses that occur being made up by a small addition of salt water when necessary. The piston-rods and connecting-rods are lettered N and O respectively, and the crank-shaft, P. Q is a cast-iron bed-plate, to which the upper parts of the engine are securely bolted; and R, R, are wrought-iron columns supporting the front of the cylinders.

Many details are necessarily omitted from the figures, but enough are shewn to give an idea of the working of the engine. It was a favourite type long before the compound principle came to be acknowledged; and the only external difference of any importance was, that the two cylinders were the same size. This is not the place to enter into arguments of a purely engineering nature for or against compound engines. We need only say that, without exception, they are being adopted by all the great steam-shipping companies; and that a careful examination of the work done by marine engines all over the kingdom during the last half-dozen years, would shew that they are superseding ordinary engines (for marine purposes) as rapidly as the screw has superseded the paddle. They are universally found to effect a very great saving in fuel; but, besides this, owing to the more advantageous distribution of the steam, the ratio of the dynamometrical or actual horse-power given out by them to the indicated horse-power is considerably greater than in engines working with anything like the same economy, but uncompounded. The effect of this is, that a certain indicated horse-power given out by a compound engine propels a given ship faster than the same indicated horse-power from an ordinary engine.* The results of numerous experiments seem quite conclusive on this point.

The engines in a steamer are generally placed as far aft as possible, the width of the vessel and the height of the bed-plate determining their position. The shaft is often made to lie at a small angle to the keel, for the sake of getting more room for the engines; although some engineers consider it an advantage on other grounds as well to have the shaft lying a little downwards towards the screw. In engines of more than 50 or 60 nominal horse-power, there are generally two or more boilers. These are always placed forward of the engines, and are now generally made cylindrical, in order the better to resist the enormous pressure of the confined steam, which is often as great as 60 or 70 lbs. per square inch, or more than 4 tons per square foot. An engraving and description of a marine boiler will be found in the article Steam-engine. The fuel used in the boilers is always coal of a superior quality, and the great object of the engineer is to construct boilers and engines which shall perform a maximum of work with a minimum of fuel. First-rate steamers with such engines as have been above described, will not use more than 2 lbs. of coal per indicated horse-power per hour. Even at this low rate of consumption, a steamer with engines of 500 horse-power nominal (or about 2000 horse-power indicated) would use over 400 tons of coal on one voyage across the Atlantic.

Some London engineers, Messrs J. and W. Dudgeon, have done more in making twin-screw steamers and engines than any other firm. The style of engines generally adopted by them of late years is very neat, and economical of space. They are called diagonal engines, and are in the form of the letter A, the cylinders being at the top, and sloping down each to their own screw-shafts, which are at the bottom of the legs. The condenser and pumps are arranged to fill up the triangular space in the middle.

It has often been proposed to propel vessels by jets of water forced through nozzles at their sides, the reaction of the sea against these jets driving the vessel forward. With this system of hydraulic propulsion, the name of Mr Ruthven is associated. In 1866 he succeeded in getting government to try his plan in the *Waterwitch*, a sister gun-boat to the twin-screw vessels *Viper* and *Vixen*. The engines were 160 horse-power nominal, and had three cylinders driving a large turbine, or centrifugal pump, which drew water from the bottom of the ship, and discharged it through the side-nozzles. This vessel was fairly successful, but not so much so as to make the Admiralty see their way to the further adoption of the hydraulic principle. It possesses some advantages—notably, that the engines would always turn in the same direction, and the reversing of the ship's motion would be effected by the altering of the direction of the jets by the captain on deck; that the turbine could be so made as to pump from the interior of the ship if necessary, and in this way a very considerable leak might be rendered harmless; and that no moving propeller whatever existed which could be damaged or fouled in any way. The chief defect seemed to lie in the design of the so-called turbine, and it is probable that when this has been more fully investigated, more will be heard of hydraulic propulsion.

NAVIGATION.

Navigation is the art of conducting vessels at sea in the direction in which they are designed to proceed. It will not be out of place here to say a few words regarding the management of a ship while on her voyage, and the instruments used by the officers to find out their position, speed, and direction, although we cannot do much more than mention them.

Tides, currents, and winds are the three natural agencies which advance a sailing-vessel on its course; the last is, of course, the most important, and the skill of the mariner shews itself in the degree to which he succeeds in rendering almost every breath of wind, from whatever quarter, useful in propelling the ship in the desired direction. The most favourable winds are those which blow on the *quarter*, or slantingly on the ship's course. The reason for this is, that when the wind blows directly astern, the sails furthest aft intercept it, and prevent its having any action on those further forward, so that only a few sails are actually of use in propelling the ship. When the wind is on the quarter, however, all the sails, when properly *braced* (turned round), can catch the breeze at the same time. The variety in rigging of different vessels causes great difference in their sailing power; some will sail much closer to the wind—that is, much more nearly towards the direction from which it is blowing—than others. When the

* This would not be the case, or, at least, not at all to such an extent, were it possible to fit marine engines with large fly-wheels.

wind becomes too powerful, certain sails are taken in altogether, and others partly *reefed*, or fastened up to their respective yards, so as to reduce the area of canvas exposed. Bracing the yards and reefing the sails are among the nicest points of seamanship.

When there are neither currents to be taken advantage of nor land to be kept away from, the captain's aim is to navigate his ship in the line which is the shortest distance between the port from which he departs and that to which he is going. Unfavourable winds, however, and other causes generally compel him to deviate from the straight track. In order to make the best use of the wind, it is often necessary to sail in a zigzag direction, alternately to right and left; this is called *tacking*. When the ship is tacking towards the left, and the wind consequently on the right, she is said to be on the *starboard* tack; and when she is tacking towards the right, on the *larboard* or *port* tack. A ship, except when the wind is dead astern, does not sail exactly in the direction of her keel, but deviates a little towards the side which is opposite to the wind. The angle contained between the real and apparent direction is called *leeway*. We may here mention that the right-hand side of a ship, looking forward, is called the starboard side; and the left hand the port, or larboard side. The weather-side is that next the wind, and the lee-side that furthest from it.

The manœuvring of a ship, tacking, shortening sail, &c. is comparatively easy work in fine weather, but in a storm calls out all the skill of the captain, and all the energies of his crew, and often requires great personal daring. Ropes called footlines hang underneath each of the yards of the larger sails. The sailors, when the order is given to reef the sail, station themselves on these, holding on by the yard, and leaning over it, and gradually haul up the sail and make it fast to the yard. It is an operation demanding steadiness and nerve, when the ship is merely sailing on smooth water; but when she is plunging headlong into every wave, or heeling over until the tip of the yard almost touches the water, reefing topsails is work which one does not care to watch, and at which many lives have been lost. Many patents have been taken out for reefing the sails from the deck without the necessity of going aloft at all, and some of these have come largely into use. The highest and smallest sails are those which, when it becomes necessary to shorten sail, are taken in first, and as the wind increases, the lower ones are also reefed or taken in. The after-sails too, for various reasons, are taken in before the forward ones. In very heavy gales, it is sometimes necessary to take in the whole from stem to stern, leaving nothing but the bare poles exposed to the wind.

The most important instrument for the guidance of the mariner is unquestionably the compass. The one most generally in use on shipboard is of the following construction: a magnetised bar of steel, called the needle, is supported horizontally on a central pivot, round which it is free to move and point in any direction. A circular card (fig. 11), like the dial of a clock, is fixed to the needle so as always to move along with it, and round this card are marked 32 equidistant points. The four cardinal points, north, south, east, and west, are indicated by their initials respectively; while the subordinate ones are marked by various letters, as NbE for north-by-east, NNE for north-north-east; and so on. To recite the thirty-two points is called 'boxing the compass.'

The card and needle are fixed in a round box with a glass face, both to secure them from the

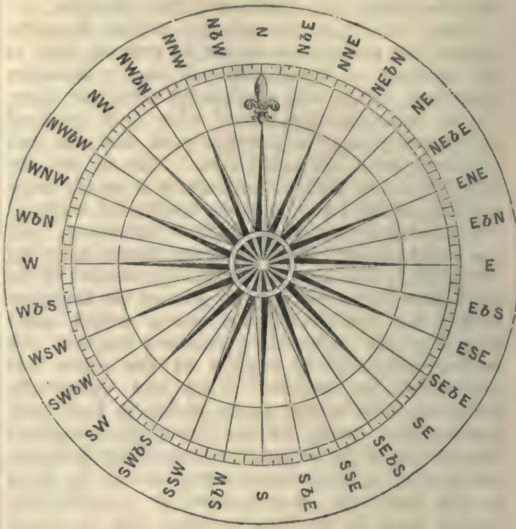


Fig. 11.

agitation of the atmosphere, and to exclude dust, moisture, and other things which might interfere with the correctness of the indications. The whole is enclosed in another box suspended by two concentric brass circles, or *gimbals*, in such a manner that the compass hangs on points like a swivel, so that no matter how the ship moves, the needle and card remain in the horizontal plane. The compass thus incased is placed upon deck in a covered brass stand called the *binnacle*, in front of the man at the helm, so that he can constantly see in what direction his ship is going.

The magnetic needle does not point (at most places on the surface of the globe) due north. The direction in which it does point varies in different latitudes, and varies also from year to year, and even (to a very small extent) at different hours of the day. In this country the needle points about 25° to the west of north.

As the needle is liable to be affected by the proximity of iron, no piece of that metal is used in the construction of the binnacle, or allowed to be near it when it can be avoided. In iron vessels, very great care has to be taken in adjusting the compasses, so that their indication may not be rendered unreliable.

Provided with a compass, the next object of importance is the *log*, an instrument for measuring the rate at which the vessel moves through the water in a given space of time. The log is a very simple contrivance, consisting of a long piece of cord, to which bits of coloured cloth called *knots* are attached at intervals, and having at one end a triangular piece of wood called the *chip*. The chip is loaded with lead, so as to make it float upright in the water. A sand-glass, running out in 15 or 30 seconds, is used along with the

log; and the distance between the knots on the line is made to bear the same proportion to a mile as the duration of the sand-glass bears to an hour. The mode of measuring the ship's speed is as follows: a sailor holds the reel on which the line is wound; and the officer, holding in his hand a quantity of loose line, throws the chip into the water, well to leeward. Before the stray line is exhausted, the chip is floating astern of the ship, and the officer watches the line until the first knot passes through his hands, and at that instant gives the order to turn the glass. As soon as the glass runs out, the person holding it cries 'Stop!' The line is grasped, and the number of knots passed off mark the speed of the ship. Self-indicating logs are also used besides the kind above described. These consist of a brass box, shaped in such a manner as to offer very little resistance to the water, with a vane-wheel like a screw-propeller attached to them. This wheel is made, by means of clockwork, to mark on an index the distance run as deduced from its revolutions. This log, instead of remaining stationary like the chip, is, of course, towed at a suitable distance behind the vessel.

The position of a vessel when it is deduced from the compass and log alone, is called her place by *dead-reckoning*. The compass points out the direction in which the vessel moves, but its indications must be corrected for variation, for deviation (caused by any peculiarity in the construction of the ship), and for leeway. The current, if there is any, must also be noticed. The *Nautical Almanac*, a copy of which every captain has in his possession, gives the variation of the compass for every part of the world; the deviation has been found out when the compasses were adjusted previous to the ship leaving port; and the officer, guided by his experience, makes what allowance he thinks necessary for leeway; depending on the force of the wind, the direction of the course, and the amount of canvas spread. The log-line is hove every hour in the navy, and every two hours in the merchant service. A journal called the log-book is kept, in which are entered (for each time of heaving the log) the speed of the vessel, her apparent course, the state of the weather, leeway, and everything else that can affect her position. From the entries in this journal, the ship's place at noon each day is carefully calculated.

The position of a ship is, however, calculated from observation of the sun, planets, and other heavenly bodies, as well as by dead-reckoning. For this purpose, another instrument is required besides those already mentioned—namely, a sextant or quadrant, instruments for determining the height of an object above the horizon. The principle of both is the same: each has a graduated arc and a system of lenses and mirrors, by which, when the object observed is made to appear in contact with the horizon, its angular distance above it can be read off by an index on the arc. The quadrant measures angles up to 90°; it has no telescope attached, and can only be used for altitudes or latitude observations. The sextant is a more elaborate instrument, measures up to 120°, and besides altitudes, is adapted for measuring the distance of the moon from the sun, or a star, &c. which is sometimes useful in determining the longitude. Just as observations by the compass must be corrected for variation, &c. the indications of these instruments must be corrected for parallax (as all angles are supposed to be measured from the centre of the earth, and not from its surface), for the refraction of the atmosphere, for the dip of the horizon, and other things, for all of which tables are provided in the *Nautical Almanac*.

The situation of any place (or the position of any ship) on the surface of the globe is determined by its distance from two imaginary lines, the equator and the first meridian. Its position in reference to these is called its latitude and longitude respectively. The equator is a fixed circle on the earth's surface equidistant from each pole. A meridian is a line on the earth's surface, extending from pole to pole in a plane perpendicular to the plane of the equator. Different nations reckon different meridians as being the first; the English reckoning from the meridian which passes through Greenwich, the French from that which passes through Paris, &c. Latitude is the distance from the equator measured on a meridian in degrees, minutes, and seconds. It must, therefore, always be from 1° to 90°; and it is called north or south latitude, according as it is measured towards one or other of the poles. It is evident that all degrees of latitude are equal,* and that each of them is equal to one three-hundred-and-sixtieth of the earth's circumference. A degree is equal to 60 nautical miles, or knots—or about 69½ ordinary miles. Longitude is also measured in degrees, minutes, and seconds, and is the arc of the equator intervening between the first meridian and the meridian of the place named. At the equator, therefore, a degree of longitude is equal in length to one of latitude, but its length continually diminishes as the latitude increases, until it is zero at the poles. Longitude is measured east and west to 180° in each direction, and it is obvious that 180° E. longitude and 180° W. longitude coincide, and are in the plane of the first meridian.

The places of the sun, moon, and many stars for every day of the year are all carefully calculated and tabulated beforehand, and the mariner has the tables with him on his voyage, so that on finding by observation the altitude and position of any of the bodies named, he may be able, by reference to the tables, to infer from that the position of the ship. As the earth revolves round its axis, successive meridians come under the sun; and as it always revolves through the whole 360° in exactly 24 hours, it passes through precisely 15° of longitude in an hour. In determining the longitude, it is, therefore, all-important to know the exact time; for this purpose, chronometers are used; they are made with the utmost precision, and so as to be unaffected by any changes of climate or temperature. The chronometer is set, on starting, to Greenwich time, so that when it shews 12 o'clock noon, the sun is exactly on the meridian of Greenwich; and during the voyage the captain has only to ascertain by the sextant the exact hour at which the sun passes the meridian in which the ship is, and convert the difference between that hour and noon at once into degrees of longitude, four minutes of time corresponding to one degree.

* Disregarding the spheroidicity of the earth.

In addition to the instruments already named—namely, the compass, log, sextant, and chronometer—every ship carries a barometer of the most delicate construction. In parts of the world where storms come on suddenly, and almost without visible warning, this instrument is invaluable in giving timely notice of their approach, and so allowing sails to be reefed and other preparations to be made, for which without notice there would not be time. The log-book of a ship has already been mentioned. In it are entered all occurrences of importance during the journey, and it is preserved with great care for exhibition when required at the end of the voyage. Charts, which differ in many respects from ordinary maps, and which are of various kinds (as plane, Mercator's, &c.), are as indispensable to the captain as his compass, and on them he daily marks the ship's position, in accordance with the reckoning and observation.

LIGHTHOUSES, BEACONS, AND BUOYS.*

These means of warning the mariner off sunken rocks and dangerous sand-banks or coasts are among the most indispensable adjuncts of maritime conveyance. More or less obscure notices exist of the lighthouses or beacons of Pharos and Rhodes, many years B.C.; but the oldest *modern* lighthouse of which we have any detailed information is the Tour de Cordouan, a tower 145 feet high, situated on a low rock three miles from land at the mouth of the Garonne. It was founded in 1584, and finished in 1610, and still remains one of the finest of its class, although, of course, all its lighting arrangements are changed from the primitive ones at first used, to the elaborate arrangements which alone are now considered efficient. It was originally lighted by blazing fagots of wood in an open chauffer—and many of the older beacons (among others one that existed on the Isle of May till 1816) were simply open coal-fires. These possessed the negative qualifications that they were liable to be almost entirely obscured at intervals by their own smoke, and that in strong gales they would only light on the leeward side, and so were entirely invisible where alone they could be of use. They thus, by the irregularity of their light, were as often a source of danger as of safety to the sailors who relied on their appearance.

The most celebrated lighthouses of our own day are the Eddystone, the Bell-rock, and the Skerryvore. The first is situated on a low and very dangerous reef of rocks, south-south-west from the middle of Plymouth Sound, and about 14 miles from Plymouth. As early as 1696, a gentleman named Winstanley obtained the necessary powers to build a lighthouse there. The building was made of wood, and was finished in 1700. So certain was Winstanley of the stability of his structure, that he declared it to be his wish to be in it 'during the greatest storm that ever blew under the face of heaven.' The tragical way in which his wish was gratified when, in 1703, the whole fabric was swept away in a night, with workmen, lighthouse keepers, and Winstanley himself, is well known. The necessity of some beacon on the Eddystone was so urgently felt, however, that in 1709 another wooden lighthouse was built by a Mr Rudyerd. This was burned down in 1755; and then arose the building which for more than 120 years braved every storm, and stood then as perfect as the day on which it was finished. This third edifice was the work of Mr Smeaton, the celebrated engineer. He fixed on stone as the material for his erection, and chose for its shape an outline resembling that of an oak tree, a graceful curve which combines intrinsic beauty with the highest degree of strength. The work was begun on 2d April 1757, and finished on 4th August 1759. The slope of the rock was cut into steps, into which were dovetailed, and united by strong cement, Portland stone and granite blocks. The tower was 68 feet high. The rock which served as its base having unfortunately been undermined by the action of the water, a new lighthouse was begun in July 1878 on the south reef, 120 yards from the old one. Like its predecessor, it is ingeniously dovetailed throughout. Its dioptric apparatus,* at an elevation of 120 feet, gives a light equal to 230,000 candles, visible to a distance of 17 miles in clear weather. It was completed in 1882, and the old one was removed.

The Bell or Inch-cape Rock is a sunken reef on the east coast of Scotland, between the mouths of the firths of Forth and Tay. Tradition says that the abbots of Aberbrothock succeeded in fixing on it a bell, which was rung by the swell of the sea, so as to warn the mariner of his situation; but that this benevolent erection was destroyed by a Dutch pirate, who, to complete the story, was himself afterwards lost on the rock with his vessel and crew. Be this as it may, it was only in 1800 that Mr Robert Stevenson, engineer to the Northern Lighthouse Board, prepared his design for a substantial lighthouse after the model of the Eddystone. He had very special difficulties to contend against. While the Eddystone rock was only submerged at high-water, the Bell-rock was barely uncovered at low-water. Only with a low spring-tide and a smooth sea could a landing be made at all, so that during the first two years, the aggregate time during which the rock could be worked at did not exceed 400 hours, in snatches of an hour or two at a tide. Operations were commenced in 1807; and the light was first exhibited in February 1811, and many were the adventures and narrow escapes during that time of those employed in its construction.

When footing cannot be had to build a tower, floating lights are used. The lightship is a vessel of about 150 tons burden. The lantern surrounds the mast, on which it is raised when hoisted. The vessel is manned by a crew of eleven men, so as to work her in case of her breaking adrift.

The subject of lighthouse illumination is one which has engaged the careful attention of modern scientific men. It depends upon mathematical and optical principles which cannot be entered upon here, but their results may be briefly summarised. The object to be attained is to collect all the light from the lamp, preventing its diffusion upward and downward, and to send it out to sea in a concentrated beam in the direction which will be most useful to the sailor. Two

* For much of the information in this section, we are indebted to a capital little book by Mr David Stevenson, F.R.S.E. entitled *Lighthouses*.

* The only light that was exhibited from the Eddystone in Smeaton's time came from a frame supporting 24 candles.

methods are in use to attain this object. The older is called the catoptric, or reflecting system. By it each lamp is placed in the focus of a parabolic reflector, which, by virtue of its curve, reflects all the rays parallel to each other out seaward. The second method is called the dioptric, or refracting system, and originated with the late Augustine Fresnel. Instead of a number of burners in the foci of reflectors, he used one large central flame, surrounded by a number of plano-convex lenses. The light, in passing through these lenses, is refracted into a beam of parallel rays similar to the reflected beam in the catoptric system. Very elaborate arrangements of prisms are used to catch all the upward and most of the downward rays, and throw them out to sea along with the rays passing through the principal lens.

If all lights had the same appearance, the sailor would often have difficulty in distinguishing one from another; each one, therefore, must have its own distinctive character. The following are the principal classes of lights: The *fixed*, which throws a steady beam in all directions; the *revolving*, in which, by the revolution of lenses or reflectors, the light is made gradually to decrease, and then again gradually to increase in intensity at certain intervals; the *flashing*, in which, by a slightly different arrangement of apparatus, the changes are sudden and rapid, instead of gradual; and the *intermittent*, in which the light is totally obscured by shades for half a minute at intervals. By the use of ruby-coloured glass chimneys to the lamps, each of these classes may be made to throw a red instead of a white light. Blue and green lights are not sufficiently visible at great distances to be of use in lighthouses.

Lighthouses near towns are sometimes illuminated with gas, but in general argand lamps are used, fed with colza oil. Of late years, many experiments have been made, under the auspices of the Trinity House, with magneto-electric lights, and in 1880 these were regularly used in some half-dozen English lighthouses; but practical difficulties still prevent their extensive use.

The management of our lights is in the hands of three public boards—namely, the Trinity House for England, the Commissioners of Northern Lighthouses for Scotland, and the Ballast Board of Dublin for Ireland. The two latter are, to a certain extent, under the control of the Trinity House, and the whole of the three, in many respects, come under the jurisdiction of the Board of Trade.

Beacons are generally placed on sand-banks, rocks, or shoals, and are either floating or stationary. When floating, they are called *buoys*, and are used both to point out the position of the hidden danger, or to mark out the course which vessels ought to follow, and as mooring-buoys, for ships to fasten themselves to in rivers or harbours. Stationary beacons may be considered to be lighthouses without lights. Their great defect is, therefore, that they are not visible on dark nights, just when they are most required. Mr Thomas Stevenson has introduced with success a mode of illuminating beacons near the shore, when it is of the utmost consequence that their exact position should be known, but when it is not expedient or possible to erect a lighthouse. This is managed by what he terms an *apparent* light, produced by placing a reflecting apparatus on the top of the beacon, to which is transmitted from a lighthouse on shore a beam of light, which is dispersed by the apparatus in the required direction; thus producing all the useful results of a light-house.

SHIPWRECKS AND LIFE-BOATS.

Notwithstanding every precaution of lighthouse and beacon, shipwrecks are continually occurring at different parts of our coasts, and to save the lives of the seamen in such cases — without reference to the fate of the vessel—has ever been a subject of earnest consideration. During last century several *life-boats* were invented, the best known being Mr Greathead's, which gained a premium offered by the inhabitants of South Shields, as well as the gold medal of the Society of Arts, and a parliamentary grant of £1200. Although various other life-boats were invented from time to time, Greathead's remained the general favourite until about the year 1851, and many of his construction are still to be seen on different points of the coast. They failed, however, occasionally; and several sad mishaps befell the crews of life-boats, especially in the case of one at South Shields, in which twenty pilots perished. Upon this the Duke of Northumberland offered a prize for an improved construction, and numerous designs were submitted, a hundred of the best of which were exhibited in 1851. Mr James Beeching of Yarmouth obtained the award; but his boat was not considered entirely satisfactory, and Mr R. Peake, of Her Majesty's Dockyard at Woolwich, was intrusted with the task of producing a life-boat which should combine the best qualities of the different inventions. His efforts were very successful, and the National Life-boat Institution adopted his model as the standard for the boats they should thereafter establish on the coasts. The boat thus adopted is from 30 to 40 feet long, its breadth being about one-quarter of its length. It is generally rowed by ten men, sitting in a double row. It is made with a great deal of sheer—that is, with the line of the gunwale much lower in the centre than at the ends. There is an air-chamber at each end and along each side; and cork is fitted in the space between the deck and the floor, or lower skin of the boat. The object of the great sheer and of the end air-chambers is that the boat may not be able, if capsized, to float bottom upwards, but may always tend to right itself. This self-righting is one of the most important qualities which a life-boat can possess. Six relieving tubes, each six inches diameter, with valves opening outwards, are fitted, to allow of the boat being emptied (to the surface-level) when filled by a heavy sea: the rest of the water is then pumped out by hand.

The importance of the life-boat in saving life can scarcely be over-estimated. Hundreds of vessels have their crews rescued through its use every year; and as the National Life-boat Institution obtains funds, this invention is being gradually extended all round the coast of the United Kingdom, while foreign nations have not been remiss in thus protecting their shores.

The *Royal National Life-boat Institution*, after an unrecognised existence for several years, was formally incorporated in 1824. Its objects are, to provide and maintain in efficient working order

life-boats of the most perfect description on all parts of the coast; to provide, through the instrumentality of local committees, for their proper management, and the occasional exercise of their crews; to bestow pecuniary rewards on all who risk their lives in saving, or attempting to save, life on the coast, whether by means of its own or other boats, and honorary rewards, in the form of medals, to all who display unwonted heroism in the noble work. It is supported entirely by voluntary contributions. It saves about 900 lives annually, and is therefore eminently worthy of support. It has now a fleet of 300 life-boats stationed all round our shores. Since its establishment, the Society has been instrumental in saving 30,000 lives; the number during 1875 being 921. It has also given rewards in cash to the extent of £50,000, besides nearly 100 gold and 900 silver medals.

The principal means of saving life in shipwrecks besides the life-boat is by rocket and mortar apparatus. This consists of a mortar, which can be made to throw a rocket carrying a light line to a distressed ship. The light line enables connection to be made between the ship and the land by a strong rope, and on this a cradle is slung, and one by one the crew of the ship are hauled safely to land in it. Nearly 300 sets of mortar apparatus are placed on our coasts, wholly provided and paid for by the Board of Trade out of the Mercantile Marine Fund.

The Wreck Register, annually issued by the Board of Trade, contains a sad account of the loss of life which, notwithstanding all our appliances, still occurs every year on our coasts. From it we learn that in the ten years ending with 1871, there were 17,086 vessels wrecked on our coasts; of these, 1713 were attended with loss of life, and the number of lives actually lost reaches the appalling total of 7910. The numbers for the year 1871 alone were respectively 1575, 135, and 636; or considerably below the average of the decade. The number of wrecks and casualties of all kinds on the British shores in the year ended June 30, 1875, amounted to 3590. In 155 cases lives were lost, the total number being 926. The wrecks and casualties for 1880–81 amounted to 3575, and the total number of lives lost was 984.

We conclude this paper with some relevant statistics. In the year 1881, there were 24,830 sailing and steam vessels belonging to the United Kingdom. Of this number, 19,325 were sailing-vessels, and 5505 were steamers. The detailed table below shews the state of the shipbuilding trade in 1875, and gives the relative importance in this respect of the chief ports. The little table prefixed is given for the sake of shewing the rapid growth of steam-shipping.

MERCHANT STEAMERS BELONGING TO THE BRITISH EMPIRE.

Year.	No. of Vessels.	Tonnage.
1820	43	7,243
1830	315	33,444
1840	824	95,807
1850	1350	187,631

NUMBER AND TONNAGE OF VESSELS, THE BUILDING OF WHICH WAS COMPLETED IN THE UNITED KINGDOM IN 1882.

Ports.	Sailing.								Steam.							
	Iron.		Steel.		Wood.		Total.		Iron.		Steel.		Wood.		Total.	
	Ves.	Tons.	Ves.	Tons.	Ves.	Tons.	Ves.	Tons.	Ves.	Tons.	Ves.	Tons.	Ves.	Tons.	Ves.	Tons.
ENGLAND:																
Hull	..	..	..	..	2	152	2	152	11	10,950	3	3,348	..	..	16	14,450
Liverpool	12	21,306	..	..	..	..	12	21,306	7	9,535	..	..	1	7	20	30,848
London	15	2,440	..	..	29	1,272	44	3,712	21	2,463	29	2,637	5	74	100	9,069
Tyne Ports	1	236	..	..	6	1,136	7	1,372	100	104,105	3	1,785	4	41	114	107,303
Sunderland	8	6,976	1	903	..	..	9	7,879	84	97,330	..	..	..	..	93	105,209
Other Ports	19	20,645	..	..	183	9,814	202	30,459	109	104,970	6	4,938	19	377	339	140,744
Total, England	55	51,603	1	903	220	12,374	276	64,880	332	329,353	41	12,708	29	499	682	407,623
SCOTLAND:																
Glasgow	36	32,274	..	..	..	..	36	32,274	78	73,323	26	30,942	2	24	142	136,563
Greenock	7	11,878	..	..	2	92	9	11,970	6	3,771	13	15,027	..	..	28	30,768
Other Ports	21	20,249	6	8,317	7	612	34	29,178	42	27,069	18	15,414	6	158	101	71,990
Total, Scotland	64	64,401	6	8,317	9	704	79	73,422	126	104,163	57	61,383	8	182	271	239,321
IRELAND:																
Total	1	2,461	3	4,655	3	282	7	7,398	9	6,644	3	6,186	..	..	19	20,228
Total, United Kingd.	120	118,465	10	13,875	232	13,360	362	145,700	467	440,160	101	80,277	37	681	972	667,172

ARCHITECTURE.

ARCHITECTURE is the art which regulates the designing and erection of buildings. It is thus associated on the one hand with the technic art, engineering, which deals with the science of construction, and on the other with the fine arts sculpture and painting, which have in all ages been useful allies in the ornamentation of architectural designs. Architecture, however, differs from both these arts. It is, like engineering, a technic or useful art, its first object being to make buildings suitable for their purpose in a structural point of view; but it differs from engineering in being, like sculpture and painting, a fine art also. In this relation it has always the further object of making buildings ornamental as well as useful. Painting and sculpture are pure fine arts independent of use; but architecture is always limited in the application of its ornament by the use and structural requirements of its productions. Hence arises the maxim now generally accepted as the true definition of good architectural design—namely, 'Ornamented construction, not constructed ornament.' This means, that architecture, however magnificent, must have its basis in its uses, and the necessities of its structural parts. Thus, a castle owes its magnificence to its lofty towers, and massive walls, and crenelated battlements, all of which arise naturally from the requirements of the edifice, and are not constructed merely for effect. A Gothic church, again, owes its beauty to the tenderness of its mouldings, the grace of its traceries and pinnacles, the lightness of its vaulting, all which are equally adapted to the requirements of the building. In the same way the ornaments of the various parts should spring from their uses, and have always done so in true architecture. Thus, the base of a column is spread out to represent a secure foundation, and the capital is also expanded to receive the pressure which is to be laid upon it, and in this way the feeling of strength and stability is obtained. String-courses are carried along at the levels of the various floors to mark the levelling of the walls to receive the joisting; and the cornice is projected at the top of the wall to throw off the water from the roof, and protect the building below. So, hood-mouldings are placed over windows, and projecting cornices over doorways, to throw off the rain; and all these necessary objects are seized upon by the architect, and made worthy subjects of ornamentation. Doorways and windows are required for access and light, and these become ornamental by their graceful forms. Buttresses and pinnacles are required to resist the thrust of arches and vaults, and these are converted from utilitarian to ornamental uses. The above are examples of 'ornamented construction;' and we shall have frequent occasion to refer to other instances as we proceed. 'Constructed ornament,' on the other hand, consists of an attempt to produce ornamental effect by some construction not required for the uses or necessities of the building—as when a house-front is carried up higher than the rest of the building, in order to produce a grander appearance than truly belongs to it; or where a building is overlaid with masses of foliage, or other decoration, stuck on without reference to the general design; or where a window-arch is made of such a shape as could not stand in the material in which it professes to be built. Vaulting made in stucco, in imitation of stone, is an example of false construction; and the erection, for ornament only, of buttress and pinnacles where there is no stone vaulting, and therefore no thrust to resist, is a striking instance of 'constructed ornament.'

From the earliest dawn of civilisation, in all lands, men have always striven to become architects, and render their abodes, whatever their nature, as solid and secure in structure, and as ornamental in appearance, as their skill and taste could accomplish. The architectural history of any people thus becomes a history of their condition at different periods. Thus, every edifice raised by the hands of man contains in it a record, quite legible to the educated eye, of the race that produced it; and if it be a large and important work, it will most probably reveal the history, the religion, and the ways of life of the people by whom it was erected. These can all be equally traced in the Egyptian tomb, the Grecian temple, and the Gothic cathedral.

Architecture thus becomes allied to history, and forms, in conjunction with archæology, an invaluable aid to the philologist in tracing the rise and progress of our race.

This historical aspect of architecture is one of its most important and interesting features, and will therefore form the basis of the arrangement of our subject in the following sketch.

EGYPTIAN ARCHITECTURE.

The earliest architecture of which we have any record is that of Egypt. It is the best constructed and best preserved of all ancient styles, and it is very remarkable that the earliest specimens remaining are the most perfect. We have no means afforded us of tracing the origin and development of architecture in this the oldest cradle of the art; but we can well imagine that long periods must have elapsed before the mechanical skill was developed which the execution of these great works displays.

The well-known pyramids are the oldest existing specimens of human architecture. They are situated near Memphis, in Lower Egypt, on the western side of the Nile, and close on the margin of the desert. There are altogether some sixty or seventy pyramids remaining, all the tombs of kings. The largest three are also the oldest—namely, those erected at Gizeh by Suphis, which is the largest; by Chepheren, his successor, which is slightly smaller; and by Mycerinus, the smallest of the three, but coated with fine red granite from Syene. The first of these measures 764 feet on

each side of the base, and is 480 feet high. It covers an area of 543,696 square feet.

The pyramids have given rise to infinite speculation as to their uses. There seems now to be no doubt that they were erected by the kings as eternal tombs for the preservation of their bodies and their memories. The cells in which the sarcophagi were placed, with the approaches to them, are constructed with the most consummate skill, and lined with huge blocks of polished granite.

The pyramids were erected by the ten early dynasties of the kings, the date of the great pyramid of Suphis being about 3000 years B.C. Many books have been written on their shape and the meaning of their forms, but the simplest solution seems to be the best—that they were designed so that the four sides should be four equilateral triangles. Besides the above great pyramids, there are numerous others of different forms, some ending in two peaks. There are also many tombs of the same date, constructed round the base of the pyramids. These have been partly excavated, and display in wonderful preservation paintings of the period, shewing the rich man to whom the tomb belonged, surrounded by his family and retainers, all engaged in their various industrial occupations. Domestic animals abound, and everything indicates peace and prosperity. It is remarkable that there is not a single representation of a soldier in all these early tombs.

Fig. 2.

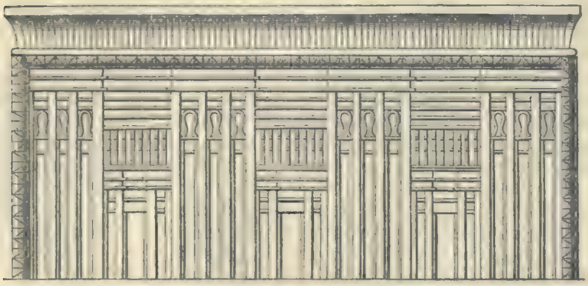


Fig. 1.—Sarcophagus of Mycerinus, found in third Pyramid. (From Fergusson's *History of Architecture.*)

We are thus enabled to realise the domestic life of the Egyptians of 3000 years B.C. with a vividness which is scarcely attained by the descriptive writings of any later period. The names of the builders are preserved on the walls, and in the case of the great pyramid, the name of Suphis was found on the wall of an inner chamber, which had not been entered since its erection till recent years. The entrance-doors of these tombs are often ornamented with carved work, shewing signs of derivation from a wooden original, a feature which we shall have frequent occasion to remark in other countries, the walls being cut as if composed of upright squared timbers with cross-beams, &c. all mortised together (see fig. 1).

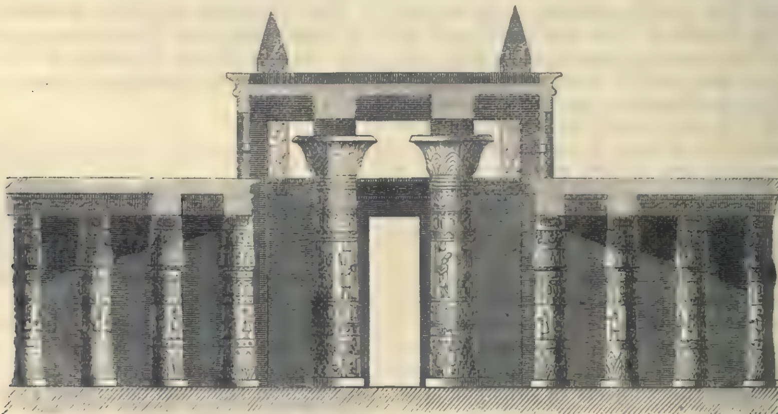


Fig. 3.—From Fergusson.

The pyramid-building kings were succeeded by the first Theban dynasties, whose monuments were chiefly obelisks, and all placed on the eastern bank of the Nile. These monolithic designs are familiar to every one, and are still greatly used as monuments to the dead. Many of the largest and finest have been carried off, no fewer than twelve being erected in Rome. One of the tombs of this dynasty at Beni-Hassan (fig. 2) is of great interest, from being the probable prototype of Doric architecture in Greece. The portico has two

fluted columns, with a square abacus, and straight lintel or architrave, closely resembling the corresponding features of the Greek style.

The greatest period of Egyptian architecture is that of the Pharaonic dynasties, extending from 1800 to 1300 B.C.—the period of the Jewish exodus. The monuments of this race are to be found in every part of Egypt, but are best preserved in Thebes and Upper Egypt. They differ entirely from the old Memphite architecture. Their buildings are irregularly set and hastily built; their tombs are long galleries cut in the solid rock; and their paintings, in place of pictures of domestic life, represent battle-scenes and conquests, and mysterious religious symbols.

Temples are the principal works of these dynasties. At Karnac, Luxor, Gournou, great temples still exist. One of these temples, called the Rhamession, is still preserved, and is a typical example. The temple at Karnac is similar to this, but of much greater extent, being 1200 feet in length, and 360 feet in breadth. Fig. 3 shews a section of the great Hypostyle Hall at Karnac, and illustrates the Egyptian style of ornament. These great palace-temples were the work of successive kings, as medieval cathedrals were of successive bishops, and thus give in one building a history of the whole style.

These great temples were connected with smaller ones by long avenues of sphinxes, and they had tanks and embankments of great magnificence. Enormous colossal statues adorn the entrance. The annexed illustrations give an idea


Fig. 4.

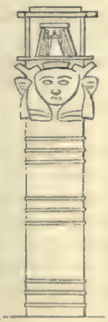


Fig. 5.

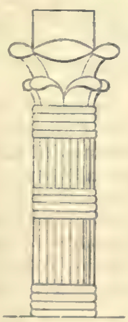


Fig. 6.

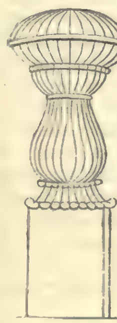


Fig. 7.

of some of the forms of Egyptian pillars, and fig. 8 shews the front of a temple.

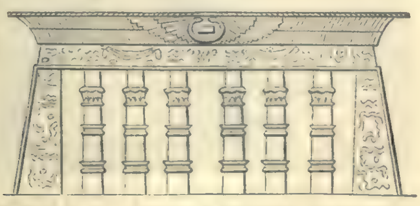


Fig. 8.—Façade of Egyptian Temple.

The tombs of this period were frequently excavated in the solid rock.

There are also smaller temples of this period called Mammeisi, which are interesting, as being the originals of the Greek 'peristylar' temples—that is, a central cell with colonnade all round.

There are almost no remains of domestic architecture to be found, but there are endless representations of houses in the paintings of the tombs, from which it is seen that they were similar in style to the temples, though, of course, small and simple, and were surrounded with fish-ponds, gardens, &c.

From the time of the Pharaohs till that of the Ptolemies, Egyptian art declined; but under the Greek rule her arts revived, and continued to flourish under the Roman dominion. But neither Greek nor Roman influence could obliterate the native art of the Egyptians.

BABYLONIAN AND ASSYRIAN ARCHITECTURE.

The people who come next to the Egyptians in point of antiquity as a building race are the inhabitants of the great plain watered by the Euphrates and Tigris. The Babylonians occupied the lower part of the country, and attained civilisation before the Assyrians of the upper country, just as Memphis preceded Thebes. Babylon is supposed to have been founded by Nimrod about 2234 B.C. but was subdued by Assyria in 1273 B.C. and remained subject to the latter till the days of Nabopolasser (680 B.C.), and his son Nebuchadnezzar, who threw off the yoke, and destroyed Nineveh in the reign of Sardanapalus (625 B.C.). But both kingdoms were overwhelmed by Cyrus, and absorbed into the great Persian kingdom (539 B.C.).

In Chaldea (or Babylonia), Assyria, and Persia, we have the history of the rise and successive developments of one great style of architecture. Unfortunately, the materials with which the Babylonians worked were of the most perishable nature, namely, sun-dried bricks and timber. In the great alluvial plain of the Euphrates, stone is awanting, and clay abounds suitable for brick-making. But there seems to have been an absence of fuel to burn the bricks, and the result is that the sun-dried bricks which were used have yielded to the influence of ages of sun and rain, and crumbled into shapeless masses of mud. During the last twenty years great progress has been made by Botta, Layard, and others in excavating these huge piles, which mark the spots where great cities once flourished; and we now know that the great temples were composed of high walls or bases of brick-work, supporting a platform on which a smaller story or platform was raised, and on this a third story, and


Fig. 9.

so on, each successive story diminishing in size till the top was reached, on which stood the cella, or temple proper. These stories were painted in different colours, according to the nature of the

deity. The platforms were of great size; the Mugheyr Temple (fig. 9) had a base 198 feet by 133 feet. The Birs Nimroud is another celebrated temple, the lower story of which is 272 feet each way. Great flights of outer stairs led from one story to another.

The architecture of Assyria resembles in its leading features that of Babylonia, but the remains here are chiefly palaces. These were always raised on huge artificial mounds, and approached by splendid flights of open stairs. The walls were, as in Babylon, built with sun-dried bricks, but they were also lined with great slabs of alabaster, covered with sculptures, and these have been preserved to us by the masses of rubbish which have fallen around them. By means of these slabs, which remain standing in their original positions, the ground-plans of the buildings can be clearly made out. They contain great audience-halls and other apartments and courts for the use of the palace. These halls were covered with flat earthen roofs (similar to those of Egypt), which were supported by wooden beams and pillars, arranged probably as we shall see in the remains of the stone architecture of Persepolis. The oldest of these palaces hitherto explored is the north-west palace of Nimroud (884 B.C.). Those of Khorsabad, Koyunjik (Sennacherib), the south-west palace of Nimroud (Esarhaddon), and others have also been explored, and their forms so far made out as to enable Mr Fergusson to publish drawings of a 'restoration' of these buildings, which, with the great courts and halls, surrounded with colossal carvings of winged bulls and lions, and innumerable carved wooden columns, with capitals of bulls' heads, &c. must have had a gorgeous, though barbaric splendour. The sculptures also represent the king engaged in religious rites, or hunting, or driving his chariot to battle. They also record the various scenes of warfare—executions, captives, &c.—and are familiar from the slabs preserved in the British Museum.

After Babylon came Pasargada—where the splendid palaces of Cyrus and Cambyses still exist in ruins—and Persepolis, the capital of Darius and Xerxes. Some remains are also to be found at Susa, Ecbatana, and Teheran. The Persians possessed and used stone in their architecture, and we here find the wooden parts of the architecture of their predecessors in Assyria reproduced in stone, and thus preserved to us.

The Persian palaces were, like the older examples, set on raised platforms, approached by great flights of steps, and supported with walls of cyclopean masonry. The halls of the palaces were square in plan, having an equal number of pillars in each direction, for the support of the flat roof. In the centre, a portion was left open for the admission of light, and sheltered by another roof raised upon pillars. The accompanying section of the Great Hall of Xerxes at Persepolis will explain this arrangement. This hall is the most splendid building whose remains exist in this part of the world. It was 350 feet by 300, and covered more ground than any similar building of antiquity, or medieval cathedral, except that of Milan. The staircases and walls are adorned with sculptures similar to those of Assyria, and the interiors were ornamented with paintings.

The use of the arch was known in Assyria (and also in Egypt): Layard has discovered subterranean arched conduits of perfect construction; and the gates of Khorsabad, discovered by M. Place, have arches springing from the backs of sculptured bulls, and are beautifully ornamented with enamelled bricks.

Fig. 10.—Section of Hall of Xerxes at Persepolis.

GREEK ARCHITECTURE.

We have seen in Egypt and Assyria the originals from which much of the architecture of Greece was designed; but before tracing the rise of the well-known styles of this country, a few words must be said on another class of remains found here, and in Asia Minor and Etruria, which belong evidently to an earlier race than the historic inhabitants of these countries. This early race is called the Pelasgian, but little is known of it except through the remains of its buildings. In Asia Minor, these consist almost entirely of tombs which have the form of a circular cone set on a high base—a design common in Etruscan tombs, and afterwards retained in Roman tombs. In Greece and Italy, the remains of the Pelasgi are interesting to the archæologist rather than the architect. They consist of remnants of tombs, city walls, bridges, &c. The tomb of Atreus at Mycenæ is a well-known example, and is a beautiful specimen of the horizontal construction of the arch. The joints of the stones are all horizontal, and not radiating, as in the ordinary arch. This form of arch, if properly weighted on the outside, or haunch, forms a very stable structure.

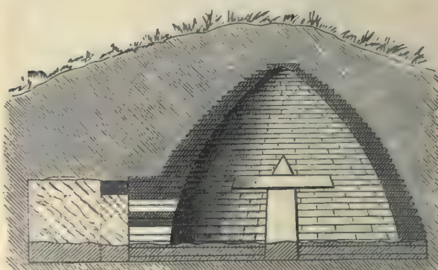


Fig. 11.—Section of Tomb of Atreus at Mycenæ.

It was at one time thought that the Greeks, from

this form of arch only being found in the country, were ignorant of the use of the true arch ; but as we have already seen that the earlier countries occasionally used the radiating as well as the horizontal form, there can be little doubt that the Greeks used the horizontal lintel, and refused to use the arch from choice, and not from ignorance. Nor is it difficult to understand the reason : the arch 'never sleeps,' but is always exerting a thrust, which tends gradually to destroy a building, whereas the lintel rests calmly in stable equilibrium.

The interior of this tomb, like many others, was covered with plates of brass, and these tombs are often known as 'treasuries.' The extensive use of brass in architecture prevailed after the Assyrian epoch : the temple of Jerusalem, for instance, seems to have owed much of its effect to the metallic coverings of the timbers with which it was constructed (after the example of the Assyrian temples already described). The Pelasgians used large blocks of stone in the construction of their great walls, sometimes laid in regular courses, and sometimes in large polygonal blocks.

Greek architecture proper does not owe much to the Pelasgi, but, as already mentioned, rather to the Egyptians and Assyrians ; but whatever forms the Greeks adopted from these countries, they so modified and improved as to stamp them with a new spirit, and purify and refine them to suit their own chaste styles.

Greek architecture is divided into three styles, called the Doric, Ionic, and Corinthian, according

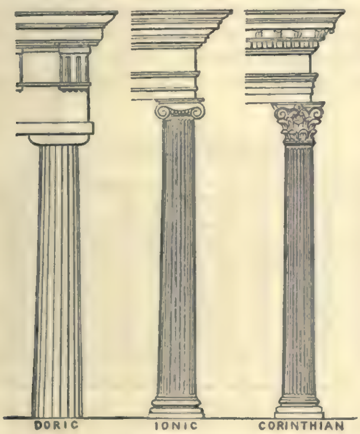


Fig. 12. Fig. 13. Fig. 14.

to the place which gave birth to each. Of these, the Doric is the oldest. The earliest example remaining is the temple at Corinth (650 B.C.). The remains of this temple shew the various members of the style fully developed, but they are all of a very massive description, strongly resembling similar buildings in Egypt. We have already seen the prototype of this style at Beni-Hassan (see fig. 2), and there are columns in the southern temple at Karnac even more strikingly similar to those of the temple at Corinth.

In the earlier styles of other countries we find a great freedom of design and variety in the arrangement of the parts, but in Greek art everything becomes more defined and fixed. The column is always circular and fluted, with a necking, ovalo, and abacus. Above the column is placed the entablature, which always comprises three parts : First, the architrave, resting on the capital ; then the frieze, and then the cornice crowning the whole. In the Doric style there are always triglyphs introduced in the frieze. It seems most likely that these parts have been derived from an original wooden style. The architrave represents the wooden lintel stretching from column to column ; the triglyphs, the ends of the cross-beams resting on it and supporting the rafters of the roof, the ends of the latter suggesting the dentils and modillions of the cornice.

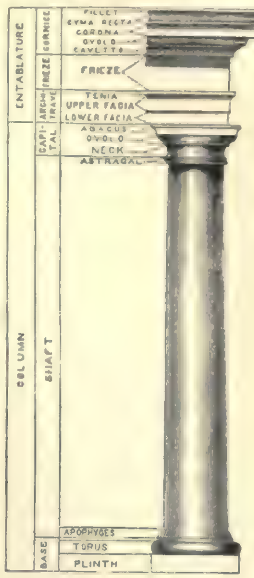


Fig. 15.—Column : Tuscan, with details.

The columns may have been originally brick piers, with a square slab laid on top, and by cutting off the corners, and again cutting off the remaining corners, a polygon was produced, which suggested the fluting of the shaft.

The Temple of Ægina is about 100 years later than that of Corinth (550 B.C.), and there is no other example till the time of Pericles, which was the great building epoch of Greece. To this period belong the Parthenon at Athens (438 B.C.), and all the best examples of the Doric style. In the countries colonised by the Greeks we also find fine specimens of their architecture.

As the Doric art progressed, the early massive forms gave place to more elegant and slender proportions. In the temple at Corinth the column is only 4·47 diameters in height ; in the Parthenon at Athens (fig. 16), which is universally recognised

Fig. 16.

as the most perfect example of the style, the column is 6·025 diameters in height. In later examples the proportions were so attenuated as to become meagre, and lost the vigour of the earlier examples.

Doric architecture is generally adorned with beautiful sculpture, for the reception of which the

architectural parts are well arranged. The lines of the buildings have all been the subject of the deepest study, for the purpose of allowing for all optical aberrations. The result is that there is scarcely a single straight line in a Doric temple. Mr Penrose has shewn, in the case of the Parthenon, that all the lines which appear to be straight are, in fact, delicate curves, so designed as to give the true effect in their various positions. Every harsh angle is softened, and every disagreeable combination of lines avoided. The columns have an entasis (or slight swelling); the architrave of the front is curved upwards, to correct the illusion arising from the sloping lines of the pediment; and the columns are sloped inwards, so as to give the greater appearance of solidity.

The Parthenon is built entirely of white marble, and the whole masonry of this and other Doric works of importance is put together with the most perfect workmanship.

There seems to be no doubt that this and other Greek temples were adorned externally with colour. To what extent this decoration was carried, is not clearly ascertained; but it is probable that the exterior walls were covered with historical pictures, which were sheltered from the weather by the portico. The sculpture was also relieved by a flat colour on the background, and the mouldings decorated with painted or gilded ornaments.

Ionic Order.—This style took its rise about 500 B.C., and as Doric was imported from Egypt, so the Ionic seems to have been originated by the influence of Assyrian art. The volutes of the capitals are particularly indicative of eastern origin. The finest examples of this style remaining in Greece are the temples of the Wingless Victory and the Erechtheum at Athens (450–420 B.C.). In the Ionian and other colonies of Asia Minor also, many fine examples of this style were erected. The celebrated Temple of Diana at Ephesus was of the Ionic order. It was the largest temple we know of up to that time, being 425 feet long and 220 feet wide. Traces of the ruins of this temple have been found within the last few months. The Ionic is a graceful style, and trusts much to carved ornament for effect. This love of ornament is another indication of an eastern origin.

Corinthian Order.—This style was the latest introduced, and combines to some extent the characteristics of both the preceding. It unites and blends together the Egyptian and Assyrian elements, the capital being probably derived from the bell-shaped capitals of the former country, ornamented with the carved leaves and spirals of the East. This order was first used about the time of Alexander the Great, the earliest example extant being the Choragic Monument of Lysicrates (335 B.C.). There are also the Temple of the Winds and that of Jupiter Olympius at Athens, the latter being one of the largest and finest examples of the style.

This style, from its richness and splendour, became afterwards the greatest favourite with the Romans, in whose hands Greek art was spread over the whole empire.

Besides the above three styles, which constitute the *Greek orders* of classic writers, the Greeks also used caryatides, or female figures, in place of columns, as in the Erechtheum; and telemones, or giants, as at Agrigentum.

Greek temples are technically classed and designated by the mode in which the columns of the porticoes are arranged. The cell, or temple proper, is a square chamber contained within four walls, the simplest form of portico, called *distyle in antis* (fig. 17) having the two side-walls continued past the end-wall, and terminated with antæ or pilasters, with two columns between. When the portico has four columns between the antæ it is called tetrastyle. The temples have generally the same arrangement of portico at both ends. In front of both ends of the plan *distyle in antis* there is frequently placed a range of six columns, and from the flank columns a row is continued along both sides (fig. 18). Such an arrangement is called peripteral, and the temple is designated 'hexastyle and peripteral.'

Fig. 17.

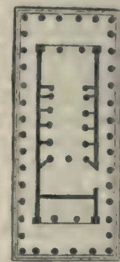


Fig. 18.

The Parthenon is an exception to the general rule, having a hexastyle portico, at each end of the cell, in front of which is placed an octastyle portico and seventeen columns along each side.

Considerable doubt has existed as to the mode adopted for lighting the interior of these temples. That suggested by Mr Fergusson seems the most probable, as being analogous to that adopted by the Egyptians and Assyrians. The interior had generally a double row of columns, with a smaller set above them, as still exists at Pæstum. Mr Fergusson supposes that the light was introduced by counter-sinking a portion of the roof, so as to admit the light between the pillars of the upper range, thus forming a kind of clerestory, as shewn in the annexed section of the Parthenon (fig. 19).

Fig. 19.

The theatres of the Greeks formed another very important class of architectural works. These consisted of semicircular rows of seats cut in the rock, or partly built. Remains of these structures are found in all countries inhabited by the Greeks, and were frequently of great size, that at Dramyssus being 443 feet across.

The proscenia were the parts on which architectural design was chiefly displayed, but these have unfortunately all perished.

None of the palaces or domestic edifices of the Greeks remain. We are thus deprived of what would undoubtedly be a very interesting chapter in the history of domestic architecture, for it is highly probable that the streets and houses of the

Greeks, although not so splendid and enduring as their temples, were more varied in style, and exhibited many picturesque and beautiful forms, which are now lost.

ROMAN ARCHITECTURE.

We have hitherto been describing styles of art which are the product of the countries in which they flourished. But we have now arrived at a stage in which is displayed a mixture of all styles. We have seen that the Etruscans established their early art in Italy as the Greeks did in Magna Græcia, and these certainly both had influence on the styles of Roman art. But with the conquest of Carthage, Greece, and Egypt, the Romans became better acquainted with the arts of those countries, and began to use them for the embellishment of the imperial city. Besides, the artists of all countries were naturally attracted to the capital. It resulted from the position of the Romans as conquerors of the world that the architecture of Rome became a mixed style, borrowing its decorative features from all sides. From Greece the 'orders' were imported, and became gradually subjected to sundry variations. Doric was used without fluting, and with cap and base and entablature greatly altered. The Ionic had the volutes turned out angularwise, so as to present a similar face in each direction. The Corinthian order was the greatest favourite, being best suited to express the taste which existed for richness and luxury in architecture. Many fine examples of this style exist in Rome (the Pantheon, Jupiter Stator, &c.) and in the provinces. The 'composite order' was invented by the Romans. It is a combination of the Ionic and Corinthian.

Fig. 20.—Doric Arcade.

The original feature in the architecture of the Romans is the introduction of the arch, which they were the first to use as a decorative feature. Long after they began to use it for structural purposes, they concealed it, but it gradually came into view. In using the Greek styles in connection with the arch, the Romans placed the columns at wide intervals, and set them on pedestals, so as to give them, with their entablatures, a proper proportion in the secondary position now assigned to them (fig. 20). Behind the columns they placed square piers, and from these threw arches which supported the wall. This favourite arrangement may be seen in all their important works. They also piled one order on the top of another to the height of several stories. As the applications of their architecture became more complicated, it was found to be impossible to bring in the 'orders' in every case, and the arch became gradually a more prominent feature. The straight architrave was thus gradually changed into an arched one, with horizontal cornice above, as at Spalatro; and when this point was gained, further progress in the development of the arched style was rendered easy, and was naturally accompanied by the extensive use of vaulting.

Fig. 21.—Courtyard at Spalatro.
(From Sir Gardner Wilkinson's *Dalmatia*.)

One of the most interesting examples in Rome is the Pantheon. The portico is of the age of Augustus, but the rotunda is probably considerably later. The temple consists of a great round hall, 145 feet in span, vaulted with a single dome, 147 feet high.

The basilicas, amphitheatres, and baths are the most numerous and stupendous works of Roman art, and all shew that, in architecture, the exterior decoration was now subordinated to the interior construction. The Basilica of Maxentius (fig. 22), with its great intersecting vaults, and vaulted aisles and buttresses, contains the germs of the later Christian styles. Roman architecture is thus more of a transition than a perfected art.

Fig. 22.—Transverse Section of Basilica of Maxentius.
(From Fergusson's *Hand-book of Architecture*.)

In it are mixed and amalgamated all ancient styles, and from it all modern styles spring. It thus forms the connecting link between ancient and modern art.

The engineering works of the Romans, such as their aqueducts and bridges, are still objects of admiration; and their triumphal arches, pillars of victory, and tombs, all deserve careful study.

Of the domestic architecture of the Romans, we have many wonderfully preserved specimens in Herculaneum and Pompeii, shewing both the arrangements and decorations of the dwellings of all classes. Of the great palaces and villas, however, none remain, except the palace of Diocletian at Spalatro in Dalmatia.

At Pompeii the houses are all one story high, and have gardens attached to them. The portions adjoining the streets are let off as shops, and the house proper is lit from the interior by courts.

We shall now proceed to trace the various styles of art which were developed from the new features (the arch and vaulting) introduced by the Romans. Their vaulting was of two kinds—namely, the plain semicircular, or barrel or tunnel vault, and the dome.

The former was the form of vaulting adopted in the west of Europe, and gave rise to all the varieties of the Gothic architecture; the latter was exclusively adopted in Byzantium and the East, and gave rise to the variety of style called Byzantine.

When Constantine gave the Christians liberty to assemble and worship, they had no style of buildings set apart for this purpose, but found the basilicas well adapted to their requirements, and used them as their churches.

The basilica was the hall of justice, and was also a place of assembly. It had two or more rows of columns running along the interior, to carry the roof, and at the end opposite the door was the apse, or circular recess in which was placed the judge's seat. In these large halls the congregations could assemble, and the judge's seat naturally became that of the bishop.

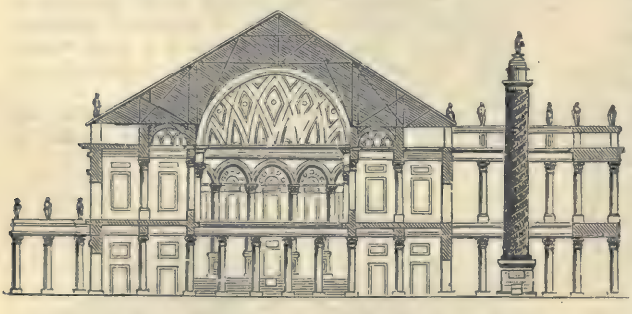


Fig. 23.—Section of Trajan's Basilica, Rome.

The altar in front, used in earlier times for libations, now served for the Christian rites. This part came in course of time to be railed in for the use of the clergy, and called the bema; and an inclosed space, called the choir, was set apart in the centre of the nave, with ambones, or pulpits, erected on each side, for the reading of the gospel, &c.

The bodies of saints were frequently buried in a confessional under the choir. The church of San Clemente, at Rome, retains all these arrangements almost unaltered till the present day. Many large basilicas still exist in Rome, and there are some fine examples also at Ravenna.

In erecting their early churches, the Christians not only adopted the plans and mode of construction of the Romans, but used the actual materials of their buildings which had been destroyed by the barbarians. Where such materials were abundant, as in Rome and Central Italy, the early Christian architecture closely resembled the Roman. In more remote districts, materials had to be found, and the designs worked out anew. Roman ornament thus gradually dropped out of use, and in each country new forms came to be invented. Between these extremes there are also instances, as in Lombardy and the south of France, where the Roman influence was strong, and continued to affect the architecture of these provinces for longer periods than in the more distant countries of the north. This produced what is called 'Romanesque Architecture,' and forms a transition from the Roman to the new style which arose out of it about the tenth century, called

GOTHIC ARCHITECTURE.

In the new style, it will be found that the vaulting regulates everything. The early Lombard and Rhenish architects seemed to be resolved to have their churches made fire-proof, and they therefore tried all they could to vault them with stone. The section on next page (fig. 24) shews the form of the wooden-roofed basilica. The central nave, resting on pillars and arches, is carried higher than the side-aisles and galleries, so as to admit of windows in the upper part of the nave walls. This row of windows is called the clerestory. The early Christian architects, following the Roman examples, had no difficulty in vaulting the side-aisles with semicircular arches intersecting at right angles; but the first vaults attempted over the central nave were plain tunnel vaults. It was found that these, besides being gloomy, required very massive walls to resist their thrust. An attempt was then made to relieve this thrust by transverse arches thrown across at intervals under the tunnel vault, to act as strengthening arches; and buttresses, with a slight projection, were applied externally to support these. This was the first attempt to throw the weight of the vault on single points; and subsequently an effort was made to throw the whole weight on these points (as in the intersecting vaults of the side-aisles). This was first managed by making each bay of the nave include two bays of the side-aisles, so as to make the arches AB and AC equal (fig. 25).

But this was not satisfactory; and after many expedients, it was found possible, by making the arches AC and BD pointed, to vault the space with intersecting arches of equal height, however much the width CD should exceed the length *a*C and *a*D. The use of the pointed arch was thus forced upon the Gothic architects as a structural necessity, and it was found so convenient and flexible,

that it gradually became applied to all the arches.

The history of all the other parts of the Gothic

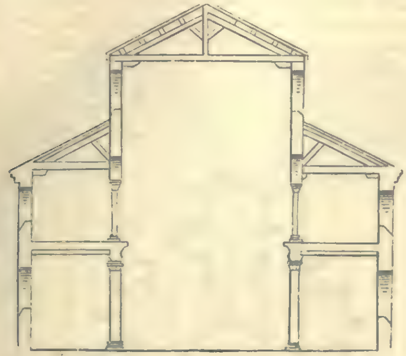


Fig. 24.

style is similar; each is a growth from structural requirement. Thus, the ribs of the vaulting were used in order to carry the weight of the vaults to

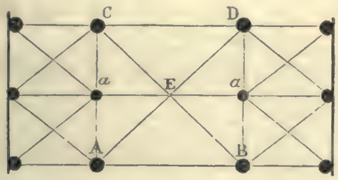


Fig. 25.

the points prepared to receive it; the nave piers from the simple column became gradually subdivided into parts, each shaft bearing on a separate cap a separate portion of the vaulting; the buttresses were enlarged and developed as they were required to resist the thrust of the groin ribs concentrated on points; and pinnacles were adopted, to add weight to the buttresses.

These principles were acted upon in different ways in the different countries of Europe. In Lombardy and the Rhenish provinces, the round arch was retained long after the pointed arch was used in France.

The full development of Gothic pointed vaulting was first carried out in the royal domain in France about the middle of the twelfth century. The old churches were found unworthy, and new and great designs were formed. The kings, bishops, and people were all united in a general impulse, under which architecture made a great stride, and the pointed style became fully developed. Of this style, the Cathedral of St Denis, founded 1144, is the earliest example. That of Notre-Dame at Paris soon followed; and contemporary with it arose the magnificent cathedrals of Chartres, Rheims, Amiens, Beauvais, Bourges, and a host of others. The introduction of painted glass also produced a powerful influence on the architecture of this period, by leading to the enlargement and increase of the windows. This process went on till the whole wall-space of each bay became absorbed into the window, and the whole clerestory became a splendid wall of glass. The annexed illustrations (fig. 26 from Notre-Dame, and fig. 27 from Tournay Cathedral) explain this progress. We here see the

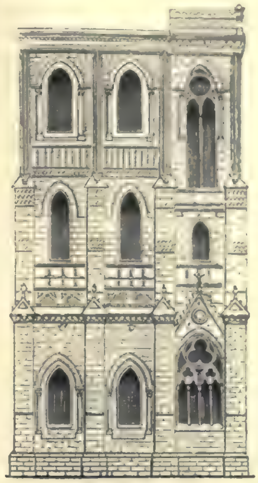


Fig. 26.

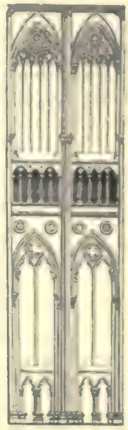


Fig. 27.

early single-arched window of Notre-Dame converted, as the style progressed, into the larger traceried windows; while in the Tournay example nearly the whole wall is cut away, to make room for traceried openings glowing with the richest stained glass.

The further history of Gothic architecture in France is simply the following out to their furthest limit the principles above indicated. So long as the Gothic architects adhered to these principles, they advanced and improved. When, however, the style had become fully developed and matured (about 1300 A.D.), the spirit of progress died, and before long a process of degeneracy set in. No new features were developed, and in handling the old traditional forms, the architects lost sight of their meaning and use, and indulged in extravagance and caprice, destructive of the original simplicity and repose of the designs. In short, the art became lost in mere cleverness of design and dexterity of execution, and the architect's place was usurped by the freemason.

It is in the cathedrals of the twelfth and thirteenth centuries above referred to that we find the noblest development of the Gothic style.

Not only did this style rapidly spread over the whole of France, but it equally rapidly extended to other countries, and took root in some of them, and thus gave rise to many remarkable varieties and beauties of design. In Spain, Belgium, and Germany, Gothic attained great development, giving rise in the last to the great Cathedral of Cologne, the completest of the Gothic cathedrals of the continent. But in no country of Europe did Gothic take deeper root than in England; and the development of the style in this country, although not so early or marvellously energetic as in France, was complete in some respects, and was much more marked by originality than in Germany or Spain.

In 1066, the Normans introduced their round arched style into England; of this many fine specimens remain, as St Cross, Hants; Durham

Cathedral; Kelso and Jedburgh abbeys, &c. But these buildings are not copies of those of Normandy. The English have always, in adopting styles, given them a national impress. The pointed Gothic was introduced by William of Sens about 1174, who superintended the building of Canterbury Cathedral. The English architects soon began to follow out a pointed style of their own. They borrowed much from France, and worked it out in their own way, forming what is now called the Early English style. The differences between the Early Gothic of France and England extend to almost every detail. The mouldings, bases, caps, pinnacles, and foliage of the latter are all impressed with the Early English feeling. In France, the feeling of the Early Gothic is one of unrest, a constant struggle forward. In England, the effort for progress is not so marked—that of carefulness and completeness prevails. In the plans of the cathedrals the differences are marked (see figs. 28 and 29), as the accompanying plans of the cathedrals of Salisbury and Amiens shew. The eastern

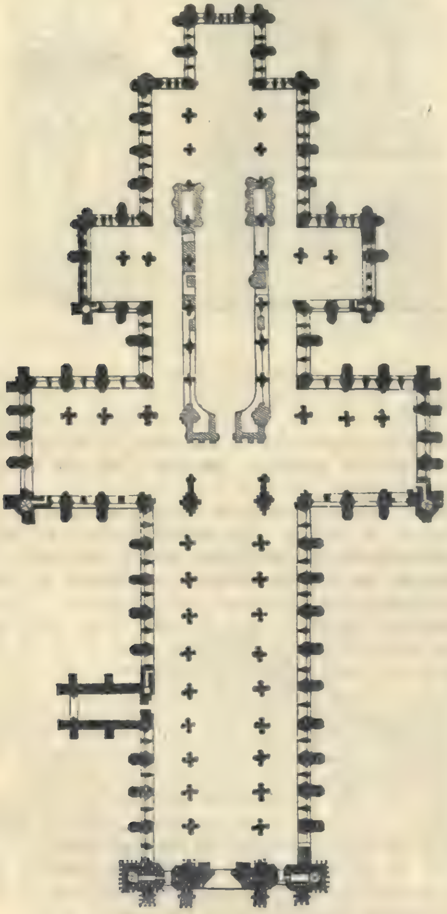


Fig. 28.—Salisbury Cathedral.

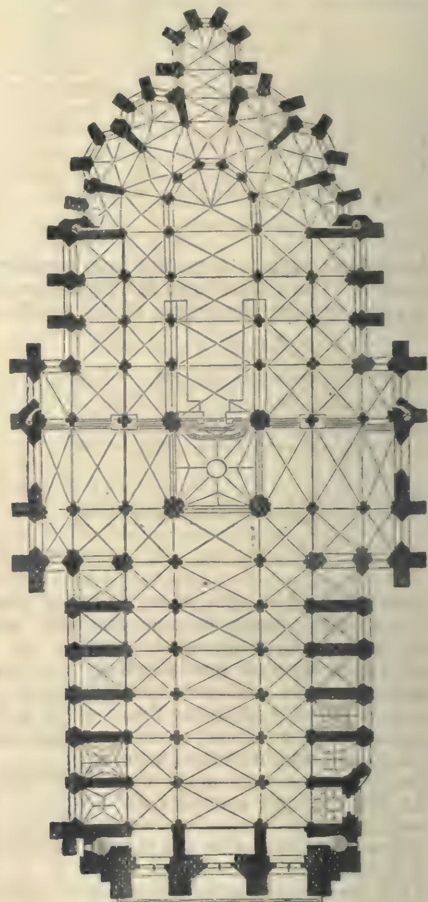


Fig. 29.—Amiens Cathedral.

termination of a French cathedral or church is invariably circular or apsidal, a form derived from the tomb-house or baptistery, which, in early Christian times, was built separately, and afterwards incorporated with the cathedral. The English cathedral, on the contrary, has almost always a square eastern end.

The French transepts have almost no projection; the English ones have great projection, Salisbury and Canterbury having two transepts. The French cathedrals are short, and very lofty; the English, long and comparatively low. The French buildings are perhaps the most aspiring; the English, the most finished and picturesque.

The Gothic architecture of England is usually divided into the following periods: first, the Pointed style, which superseded the round Norman style about 1175. Its first or 'Early English' development lasted till about 1275, when the 'Decorated' or perfected style was introduced. This style also lasted for about a century, and was superseded by the late pointed or 'Perpendicular' style, lasting till about 1483. After this came the last phase of Gothic, called the Tudor or Fan-tracery style, which was finally superseded by the Classic Renaissance. Of these periods it is impossible here to give a minute account. The simple lancet or pointed windows of the Early English period were superseded by the larger openings of the Decorated period, filled with geometric tracery (fig. 30). In the Perpendicular period the tracery becomes composed of upright lines

(fig. 31), and in the Tudor style the fan-tracery vaults (fig. 32) form the distinguishing features. Every other feature, every moulding even, is characteristic of its period; but we cannot at present

Fig. 30. Fig. 31.

describe them more fully. We may, however, state generally, that both in France and England, the style had a complete existence. It was born, arrived

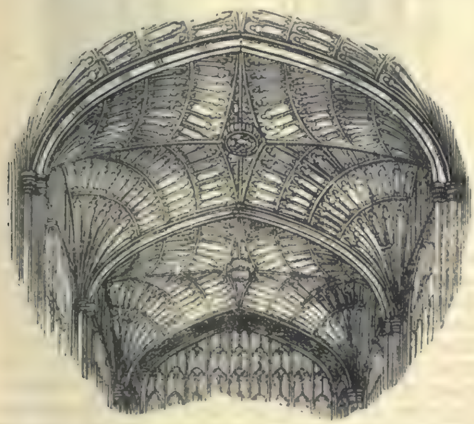


Fig. 32.—Fan-tracery: from King's College Chapel, Cambridge.

at maturity, and died. When the spirit of the early architects had pushed the design to its utmost limits, they rested from their labours, well satisfied with their splendid achievements. Their successors occupied themselves with forms and details, and the perfecting of every minute part. The art finally passed away, and left architecture in the hands of trade corporations—masons, carpenters, plumbers, &c.—who monopolised the whole work, and acted independently, to the exclusion of one directing mind, and the art became lost in the artificer's skill. The late Gothic of Germany is a most striking illustration of the stone-cutter's art and the draughtsman's ingenuity, in which the feeling of the artist is entirely awanting.

In Italy, the Gothic style never took a firm hold. Some of the Gothic buildings of Italy are, however, remarkable for their size, such as San Petronio at Bologna, and the Cathedral of Milan. The former well illustrates the defects of Italian Gothic. There is a want of variety of parts to give scale, and indicate the size of the building. It has a cold bare feeling, such as is never experienced in the north, where all the parts in large edifices are *multiplied*, not enlarged, as in this instance.

In a true Gothic building of large dimensions, the shafts and columns remain of the same size as in a smaller building, but their number is increased, and thus by multiplicity and variety, size and proportion are attained.

The same spirit which actuated the designers of the Gothic cathedrals, influenced all the products of Gothic art, down to the minutest instrument or ornament. Domestic, military, municipal, and all forms of architecture, were impressed with the same influence, as the magnificent town-halls of Belgium and Italy, and the stately castles and mansions of France and England, still testify.

BYZANTINE ARCHITECTURE.

While the Gothic styles were growing from the debased Roman architecture, in the west of Europe, another style, taking its origin from the same late Roman forms, was developed in the Eastern Empire. It was after the building of Constantinople that the divergence of style took place. We have seen that Gothic owes its forms chiefly to the nature and exigences of the vaulting. The same is the case in Byzantine architecture. The Goths adopted the square intersecting vault, while the Byzantines clung to the dome; and from these different forms of vaults may be traced the leading features of each style.

There are many examples of the early efforts of the Byzantines to adapt the circular dome to a rectangular building still to be found in the eastern provinces; but the building in which all these endeavours culminated is Santa Sophia, erected by Justinian, 537 A.D. This church has one great dome 100 feet span in centre, and a half-dome at each end. The arches are all semicircular (there being no requirement of the pointed form in this style), and the columns of the most exquisite marbles.

The same features distinguish the later Byzantine styles, variously developed in the different countries, such as Greece, Turkey, Armenia, &c. in which it prevailed. In Russia, the same forms prevail to the present day, but Russian architecture is its most barbaric type.

To some extent connected with Byzantine art was the Saracenic architecture, which arose towards the end of the seventh century. It must, however, be observed that the Arabs themselves had at first no architecture; they adopted the styles of the countries they conquered. But great variations were introduced, according to local circumstances. In Egypt, the Mosque of Ibn Touloun at Cairo (876 A.D.) shews the Saracenic style well advanced in all its forms and details. These mosques consist of a great court surrounded with colonnades, and having niches in the wall towards Mecca.

The annexed illustration (fig. 33) of one of the windows of this mosque gives a good notion of the style, and shews the peculiar tracery adopted by the Saracens. In Spain, the mosque at Cordoba (790) and the Alhambra at Seville (1250) are characteristic examples.

In Constantinople the mosques are not pillared courts, like those above described, but are buildings

roofed with domes after the manner of Santa Sophia. That of Suleiman the Magnificent (1550) is one of the finest. The minarets which adorn

Fig. 33.—From Fergusson.

the mosques are amongst the most beautiful features of this style.

In Persia and India, there are many splendid examples of this pleasing but fantastic style.

ITALIAN ARCHITECTURE.

We have now followed the various styles which succeeded the architecture of Rome in the different parts of Europe, and we have seen that these styles had exhausted themselves, and were prepared for a change. In Italy, there was even during the middle ages a certain leaning towards the classical forms of the existing Roman buildings. But it was the revival of classical literature that gave the great impetus to the re-introduction of the old classical features. The modern Italian style may be defined as Roman architecture applied to the forms and requirements of modern buildings. It is well adapted to domestic purposes, but not so suitable for ecclesiastical edifices. There are three schools of 'Italian architecture'—namely, the Florentine, Roman, and Venetian. In the first and last, the Roman details are freely used, but the medieval general arrangements are only slightly departed from. The Renaissance palaces of Venice have the same disposition of parts and general arrangements as their earlier prototypes; while the Italian palaces in Rome more closely adhere to the ancient models, so plentiful beside them. The Venetian style, being the most picturesque, was speedily imitated north of the Alps. The invention of printing spread a knowledge of classical literature and art over Europe, and a taste for classic architecture rapidly arose.

France, from her proximity to and intercourse with Italy, was the first to introduce the new style north of the Alps.

The Renaissance buildings in Italy were chiefly churches, Saint Peter's at Rome being the great model; but in France and England, the stock of churches was ample, and as people were now beginning to turn their attention more to domestic architecture, we find the early application of this style chiefly in houses and castles. In France, the châteaux of the early Renaissance are very abundant, and strongly resemble in general features their Gothic predecessors. It is only on close inspection that the classic details ingrafted on the early forms are detected. This picturesque style gradually yielded to the classic influence, and for about a century the style used was mixed

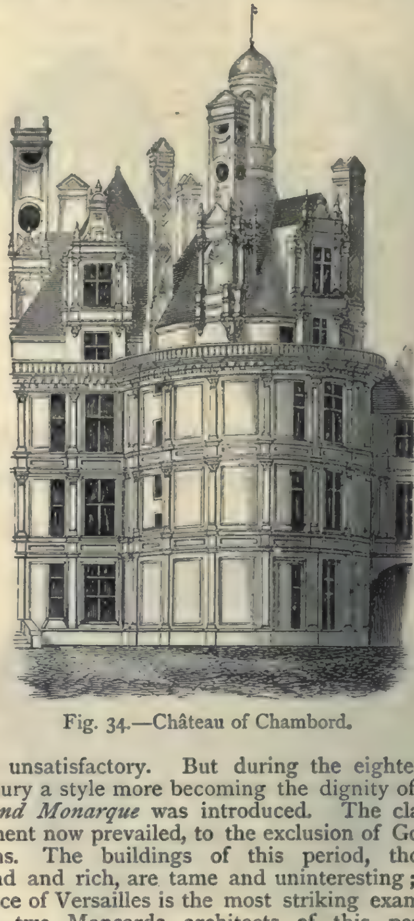


Fig. 34.—Château of Chambord.

and unsatisfactory. But during the eighteenth century a style more becoming the dignity of the *Grand Monarque* was introduced. The classic element now prevailed, to the exclusion of Gothic forms. The buildings of this period, though grand and rich, are tame and uninteresting; the palace of Versailles is the most striking example. The two Mansards, architects of this period, introduced the device of giving a row of separate houses the appearance of one palace. This idea has been universally followed in modern towns. It is one of the falsest ideas of the Renaissance, and has almost entirely ruined street architecture.

The classic Renaissance was completed in the beginning of the present century by the literal copyism of ancient buildings. Hitherto, architects had attempted to apply classic architecture to the requirements of modern times; now they tried to make modern wants conform to ancient architecture.

In the Madeleine, for instance, a purely peripteral temple is chosen as the object to be reproduced, and the architect has then to see how he can arrange a Christian church inside it! But this was found to be an impossibility, and the architecture a sham.

The result has been, that in France this cold and servile copyism is now entirely abandoned, and the French are working out a free kind of Renaissance of their own, which promises well for the future; and is at the present time, as the new streets of Paris testify, the liveliest and most

appropriate style in use for modern street architecture.

The course of the Renaissance in England was similar to its progress in France, but slower. It was more than a century after the foundation of St Peter's, that Henry VIII. brought over two foreign artists to introduce the new style. Of their works, we have many examples at Oxford and Cambridge, in the latter half of the sixteenth century. Little classical feeling prevailed till about 1620. The general expression of all the buildings before that date is essentially Gothic.

The pointed gables, mullioned windows, oriels, and dormers, are all retained long after the introduction of quasi-classic profiles to the mouldings. This style is called 'Elizabethan,' and corresponds to that of Francis I. in France.

This was followed in the reign of James I. by a similar, but more extravagant style, called Jacobean, of which Heriot's Hospital in Edinburgh is a good example, the fantastic ornaments, broken entablatures, &c. over the windows being characteristic of this style, as they are of the time of Henry IV. in France.

Inigo Jones (*temp.* James I.) was the first architect who introduced the true Italian features into England, and they then became more generally adopted.

In the latter half of the seventeenth century, Sir C. Wren rebuilt St Paul's and many other churches in London in this style. During the eighteenth century, classic feeling predominated, and gradually extended to all classes of buildings, the requirements of which were sacrificed here, as in France, to the stately inflexibility of the classic art. St Pancras Church in London is a good example. It is made up of portions from nearly every temple in Greece.

After the revival of classic art had been pushed to the extreme point above indicated, a natural reaction arose, and about the beginning of this century, a return to Gothic architecture was commenced. A very large number of churches has been erected in the Gothic style within the last twenty years, both in this country and on the continent. The most magnificent modern example is the Palace or Houses of Parliament at Westminster.

The course of architecture during modern times has been similar in Germany, Russia, and every country in Europe, to that in France and England.

Of the other countries of Europe, the only one which deserves remark for its Renaissance buildings is Russia. St Petersburg is, of all the cities of Europe, the one which best merits the name of a city of palaces. From the date at which the city was founded, these are necessarily all classic in character, and are nearly all the works of German or Italian architects. They are, unfortunately, in the coldest and dullest style, the palaces being ornamented with large pilasters, crowned by broken entablatures, and ornaments of the flimsiest rococo.

It is fortunate that we find, as above indicated, in many quarters a strong desire to throw off the thraldom of the earlier styles, and already both in Classic and Gothic there is promise of free and independent action. Let us hope that, by a natural and judicious system of selection, the architects of the latter half of the nineteenth century will develop a worthy style out of the principles so carefully and painfully laid down for them by their predecessors of the first half of the century.

INDIAN ARCHITECTURE.

The styles of art which have flourished in India and other eastern lands vary, as elsewhere, with the religion prevalent at different times. The earliest of these faiths of which we have any structural monuments is that of Buddhism. The earliest monuments of this religion date from the time of Asoka, a powerful monarch, who about 250 B.C. became a strenuous supporter and propagator of Buddhism. From his time to the present day the architectural sequence is unbroken, and the whole history of Buddhist architecture can be traced either in India or in Ceylon, Java, and Tibet, where this faith still flourishes, although now extinct in the land of its origin. The best account of these Indian styles is contained in the *History of Architecture*, by Mr Fergusson, who has devoted much time and attention to the investigation of Indian art.

The earliest Buddhist remains consist of pillars erected to contain edicts of the Buddhist faith. These are frequently crowned with a lion standing on a carved capital, in which we recognise a strong resemblance to the honeysuckle ornament of Assyria and the carving of Persepolis. Other points of resemblance seem to point to an Assyrian origin.

The strictly architectural remains of Buddhism are of two kinds: first, Sthupas, or topes—monuments erected to commemorate events, to mark sacred spots, and to contain relics; second, Chaityas, or churches, and Viharas, or monasteries.

The topes consist universally of a dome-shaped mound, topped by the tee, or relic shrine. The dome is solid, being built with bricks and mud, and the exterior faced with dressed stone. The tope has a raised base, and is surrounded by a rail carved in stone, but evidently copied from an earlier wooden fence. The gates are also clearly of wooden origin, and are covered with fine sculpture. From the above closeness of imitation of wooden forms, these are evidently examples of the early developments of a style. The topes are often accompanied with circles of standing stones and burial-mounds; in fact, the tope is probably a lineal descendant of the ancient tumulus.

Of the chaityas and viharas no built examples remain; they are all excavated out of the solid rock. The oldest are at Bahar and Cuttack, in Bengal (200 B.C.), but they are few in number, nine-tenths of the caves being in the Bombay presidency. The latter date from the beginning of the Christian era to the tenth century. The cave-temple at Karli (fig. 35) is one of the largest, and is of a good style. In plan and general arrangements, it strongly, though no doubt accidentally, resembles a Christian basilica, with nave, aisles, and vaulted roof, and an apse, with the shrine in the place of the altar. There is also an outer hall or atrium, and a gallery like a rood-loft. On the roof are numerous wooden ribs attached to the vault. These and other portions indicate that the building from which the cave was copied was wooden, which may account for the absence of earlier-built examples. This cave is 126 feet long, 45 feet 7 inches wide, and 40 to 45 feet high.

The vihara, or monastery, consists of a central

hall, with cells round three sides, and a verandah on the fourth side, next the open air. Opposite the central entrance there is usually a large cell or shrine containing an image of Buddha. There are five caves of this kind at Ajunta, Baugh, &c. many of them beautifully carved and painted.

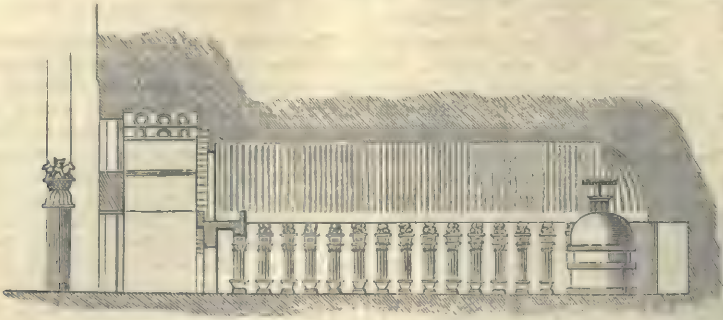


Fig. 35.—Section of Buddhist Cave-temple at Karli.
(From Fergusson's *Handbook of Architecture.*)

The pillars are most elaborately ornamented, and have the bracket capitals which distinguish all Indian architecture.

From the absence of any built example, there has been great difficulty in forming a correct idea of the exterior of the buildings from which these caves were copied. The Temple of Brambanam, in Java, seems to shew the original form of built cells. They are quite detached, and arranged in a square round a central temple, evidently suggesting the disposition of parts in the caves at Ajunta. In Burmah, where the monastic system still prevails, the monasteries, which are of wood, are built in stages in a pyramidal form. The Temple of Boro Buddor, in Java (fourteenth century), has a similar arrangement. It is a nine-storied square pyramid, each story having a terrace running round it, with a range of cells roofed in with spires and pinnacles of the most varied and fantastic outline. Each cell contains a figure of Buddha, instead of the priests who occupied the earlier examples, a change of destination quite common in Indian architecture.

In many styles of architecture, the niches or other subordinate parts are frequently copies on a small scale of the façade of the building itself. Thus, the windows with pillars and pediments in classic architecture are a repetition of the temple end. The niches inside the caves, containing statues of Buddhist saints, are in a similar manner imitations of the main façade. In the same way externally, the Burmese pagodas and Hindu temples are ornamented all over with models of the buildings themselves.

The buildings connected with the Brahmanical religion are divided into Northern and Southern Hindu architecture. All the finest examples are southern, and are found south of Madras. The temples consist of the temple proper, called the vimana, always square, with a pyramidal roof; the pillared porch, or mantopa, in front of the door leading to the cell; the gate pyramids, or gopuras, forming the entrances to the quadrangular inclosures which surround the vimana; and the pillared halls, or choultries. The temples seem to be derived from the Buddhist examples, the transformation of the cells being carried further than already pointed out, and being now mere niches with images. In the south, the temple is always pyramidal, and in many stories; in the north, the outline is curved, and in one story. The finest example is the Pagoda of Tanjore. It is 82 feet square at base, and fourteen stories, or about 200 feet, in height. The gopuras are similar to the pagodas, but oblong in place of square.

Fig. 36.—Gopura, or Gate:
Leading into the inclosure of the temple at Seringham.

The pillared halls are very wonderful structures, containing sometimes as many as 1000 columns, and as these are usually of granite, and all elaborately carved, and all different, the labour of their construction must have been enormous. They are used for many purposes connected with Hinduism, their most important use being as nuptial halls, in which the mystic union of the divinities is celebrated.

The Jaina style is distinguished from that of the Hindus by its domes. The temples consist of a sanctuary surmounted by a spire; in front of this, a pillared vestibule, with a dome; and round the whole an arcaded inclosure, with cells all round, containing images.

When the Mohammedans conquered India, they imitated the styles of that country in their

mosques, and afterwards the Hindus borrowed from them, and thus a mixed style was created, which in the palaces, tombs, &c. of the native princes produces many picturesque effects. The tombs of the Mohammedans have a strong Saracenic influence in their designs, and are among the finest specimens of architecture in India. The Tomb of Mahmoud (built 1626) at Bejapore is the largest, and the dome with which it is vaulted is supported on a series of pendentives of very ingenious and beautiful construction. The opening is 97 feet in diameter, and 175 feet high. The Great Mosque at Delhi (fig. 37), and the Pearl Mosque at Agra, are among the most elegant specimens of Moslem art.

There is one very remarkable fact connected with Indian architecture—namely, that although the *form* of the arch is constantly used, in domes, arcades, &c. especially in the style borrowed from the Moslems, yet the radiating arch construction is never adopted. The architraves are supported on bracketed capitals, which project, bracket over bracket, till the space is spanned by one lintel. This leads to many beautiful results in the early styles, and in the later mixed style the bracketed cornices are amongst its finest features.

Fig. 37.—Section through the Great Dome of the Jumna Musjid.
(From Fergusson.)

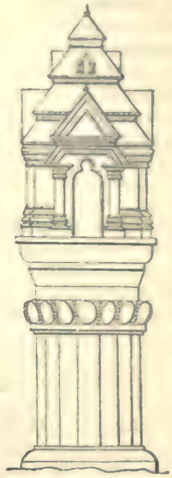


Fig. 38.

The temples of Cashmere and Cambodia form a new and interesting feature in the study of eastern architecture. We have already seen that the earliest specimens of Buddhist art contain a strong affinity with the Assyrian and Ionic styles. In Cashmere and Cambodia, the resemblances are even more complete. The illustration (fig. 38) from a Cashmere temple shews the egg enrichment and the fluting of the pillar, which are so distinctive of Greek art. It is only within the last few years that the architecture of Cambodia has been discovered and partly illustrated; the illustrations being due to the enterprise of Mr J. Thomson, a photographer. Little is known of the history of the monuments of Cambodia, but they appear to range from about 1150 to 1350 A.D. The Temple of Nakhon Wat (fig. 39) is among the most important. It is square, and extends about a mile in each direction, having a walled inclosure and moat, with a great gateway, or gopura. There are small temples and arcades within the inclosure. The size of the whole is not much inferior to that of the Great Temple at Thebes. The colonnades have a strong resemblance to the Roman Doric order, with similar capitals, though somewhat more ornamented, surmounted by an architrave, frieze, and cornice of very classic outline. The arches which cover in the arcades are pointed, and constructed in the Pelasgic or Indian manner with horizontal joints. The walls are covered with elaborate

Fig. 39.—Interior of Corridor, Nakhon.
(From Fergusson.)

bass-reliefs, representing battle-scenes, &c. The interior contains large halls or tanks for holding water, surrounded by numerous columns arranged in an artistic manner. In this temple, all the forms are essentially of the Roman Doric order, as those of Cashmere are of the Greek. No such pillars occur in India, and no Indian bracket capitals or pillars occur here. As yet, no clue has been found to the history of this remarkable style.

The architecture of China was at one time attempted to be 'revived,' and introduced into this country; but more recent investigation has shewn that in that country, so remarkable for its ancient civilisation, scarcely a building exists to record its past history or its present greatness. The temple of the Great Dragon at Pekin, and the Buddhist temples, resemble Indian architecture, but are very inferior in extent. The pagodas, the appearance of which is so familiar to us, are exaggerated tees of dagobas. The porcelain coating with which they are adorned produces a novel and brilliant effect.

Like the architecture of Cambodia, that of ancient America forms a puzzle to the historian. There are certain resemblances between Asian and Central American art, but it is impossible at present to point out any connection between them. When the Spaniards conquered Mexico, they found cities and large buildings. The principal monuments are the teocallis, or temples: these are pyramidal, with a temple or cell on the top. They are of all ages, from four or five centuries before the Spanish conquest. These pyramidal platforms are similar in idea to those of Assyria, being lofty bases on which to set the temple conspicuously. Some of the buildings are, however, of a more original style, such as that at Mitla. The walls slope *outwards* from the base upwards (a feature unknown in any other style). The panels are filled with frets and new peculiar forms. In Yucatan, the buildings are similar to those above described, some of them shewing distinct traces of a wooden origin. The horizontal arch is also used.

We have seen that all true architectures have had a gradual and natural growth. No style was ever created by one man, so that all the calls we so often hear on the architects of the present day to produce some original style must be in vain. By endeavouring each man in his own sphere to design in accordance with the actual needs of the case, a true feeling will be introduced, which will soon produce good fruit. As above pointed out, French domestic and English ecclesiastical architecture are now rapidly freeing themselves from the trammels of copyism.

PRACTICAL ARCHITECTURE.

In designing a building, the architect must first ascertain as nearly as possible what the requirements of the case are. This is sometimes a very difficult matter, from the vagueness of his instructions.

The architect then prepares 'sketches,' shewing on the 'plans,' which represent the appearance of a house if cut through horizontally at any point, the accommodation or arrangement of the rooms, windows, doors, stairs, &c.; and by the 'elevations,' the geometrical representation of the exterior of the different sides. When the sketches, which are usually to a small scale, are approved of, the working drawings and specification are next prepared. The former shew the 'plans' and 'elevations' carefully drawn out to a larger scale, all the constructions being accurately considered, and the dimensions all marked on the drawings. The 'specification' contains a minute account of every part of the works to be done. These are generally divided into mason's and excavator's, carpenter's and joiner's, plumber's, plasterer's, smith's, slater's and glazier's works; each contractor for one or more of these departments being bound to carry out the work in accordance with the plans and specification. Before estimates are taken from contractors, the drawings and specification are all measured by a surveyor, who prepares 'schedules' or 'bills of quantities,' shewing the exact amount in yards, feet, &c. of all the materials and workmanship which will be required to complete the works. These schedules are like a blank account prepared beforehand, and each contractor prices the bill at the rate he undertakes to do the work at. These rates are useful in checking excessive charges; the builder being bound to execute more or less work as may be required at the rates stated in the schedules. When the schedules are given in, and the contracts entered into, the architect proceeds to make out numerous large drawings of all the ornamental parts of a building, all the mouldings having to be drawn in section to the *actual size*, for the guidance of the workmen. All the ornaments, such as capitals of columns, &c. have also to be drawn out to the actual size. In the same way, drawings for doors, windows, shutters, and all wooden finishings, must be furnished of the full size.

WARMING—VENTILATION—LIGHTING.

WARMING.

THE average temperature of the human body is from 98° to 100°; and whether the individual be exposed to a tropical or to an arctic climate, his blood never rises above or falls below the medium more than one or two degrees, whatever his feelings of heat or cold may be. It seems as if this amount of heat, and no other, were consistent with the existence of warm-blooded animals; for if by any means the temperature of an animal's body is reduced below the above limit, its vital action declines, and soon comes to a stand. In like manner, when heated seven or eight degrees above its usual warmth, the vitality is destroyed.

The temperature thus necessary for the life of the body, is maintained by the action of that life itself. Objects surrounding the body being in almost all cases colder than it, are constantly stealing part of its warmth; but within the system there is an incessant process of combustion going on, producing fresh heat, exactly as the fire in a grate does. When the heat thus generated is not dissipated fast enough, so that the body tends to become warmer than the due degree, the accumulation finds vent in perspiration, the evaporation of which carries off the excess (see NATURAL PHILOSOPHY). In general, however, the tendency is the other way; the heat of the body, if allowed freely to escape, would be dissipated faster than it is produced; and hence arises the necessity of clothing, houses, and other means of retarding its escape. The lower animals are in general provided by nature with coverings for this purpose, according to the requirements of the climate in which they live. Man is left to the exercise of his inventive faculties to provide clothing and shelter for himself. In the lower animals, too, the heat-producing function is more active than in man. At least, this is true of civilised man; for there can be no doubt that the naked and painted savages that inhabited these islands 2000 years ago had a power of resisting cold unknown to us their descendants. Even in civilised communities, those that lead a life of activity in the open air require far less protection from the cold than those that live indoors. There is, besides, the greatest difference in this respect between individuals, though placed in exactly similar circumstances—a difference intimately connected with the soundness of the digestion and other nutritive processes.

The feelings of buoyancy which most persons in tolerable health experience during a clear frosty day, have led to a general belief in the peculiar healthiness of cold weather. But the statistics of death and disease tell a different tale. The Reports of the registrar-general shew that, exactly as the thermometer sinks, the rate of mortality rises, and certain diseases of the most fatal kind become more prevalent; the vitality, in short, of the community decreases as the warmth of the atmosphere decreases. We believe it to be an established fact, that the means generally taken to arrest the waste of heat from our bodies, or to supplement it, are, for the majority of men and women, insufficient, or injudiciously managed. This is a matter of literally 'vital' moment to one and all. The economy of heat is a primary element in the art of living in health and comfort; and no 'knowledge of common things' that we can think of, can surpass in importance a right understanding of the principles and facts on which that art rests.

We have as yet spoken of arresting the dissipation of the natural heat by clothing and shelter; and this, among some nations, is made to suffice. Where fuel is scarce, the resource against the cold of winter is thick clothing indoors as well as out. This is said to be the regular practice in China; and even in the south of Europe, fires are dispensed with in weather when we should think them absolutely necessary, and additional wrappings are considered as appropriate while sitting in the house, as in the open air. But wherever fuel can be had, it is always preferred to wear within doors much the same clothing in winter as in summer, and to keep the apartments nearly at summer temperature by artificial heat. It is this special branch of the subject, namely, the artificial warming of apartments, that we are at present to consider; that of Clothing will be treated in a subsequent number (see also PRESERVATION OF HEALTH).

In order to regulate temperature, we must first know the nature of heat—how it is produced, and what laws it follows. This forms a branch of the science of Physics, and has been briefly treated in NATURAL PHILOSOPHY. But for the better understanding of the present subject, it may be well to say something more here of

Combustion,

Which is the chief source of artificial heat. Combustion consists in the rapid union of the oxygen of the air with some substance for which it has a strong chemical attraction, and which is called a combustible or fuel. All chemical combination produces heat; but it is only called combustion when the heat is so intense as to produce light. The cheapest combustibles or fuels are coal, wood, peat, coke, and charcoal, which consist chiefly of two simple bodies or elements, carbon and hydrogen (see CHEMISTRY). Before oxygen will unite with the combustible, the latter must be heated to a high pitch; the combustion once begun in one part of the fuel, is then sufficient to keep the rest at the combining temperature, provided the heat is not too rapidly dissipated. One piece of fuel will seldom keep alight alone; a number of pieces require to be burned together, in order to keep one another warm. To blow cold air rashly into a weak fire, puts it out, by suddenly cooling the coal below the combining point. A cold poker held near the flame of a candle will extinguish it;

and a fire, on the other hand, burns much better when surrounded by bricks, than by metal. The bricks act like clothing, and keep in the heat of the coals; the iron being a good conductor, runs away with the heat as fast as it is generated, and passes it into the wall, making the coals that touch it dull and black.

Products of Combustion.—The carbon of the fuel unites with $2\frac{2}{3}$ times its weight of oxygen, forming carbonic acid gas, and the hydrogen with 8 times its weight, forming water in the state of vapour or steam. For the complete combustion of a pound of coals of average quality, about 230 cubic feet of air are required; of which some 46 feet are oxygen, and the rest nitrogen, which takes no part in the combustion. This nitrogen mingles with the carbonic acid and vapour before mentioned, and the whole ascend from the fire in the form of a heated gaseous current, which, when the combustion is complete, is colourless as common air. Were the fuel composed of carbon and hydrogen alone, these would be the only products of perfect combustion; *ashes* arise from earthy incombustible substances in the fuel, which lessen its value. If the fuel contain water, the water is driven off in steam, and carries away a great deal of the heat of the fire in a latent form. From this cause, green wood gives little heat; and coals when wetted give less than the same quantity burnt dry.

The really valuable product of combustion is the heat evolved. There are various ways of measuring its amount—as by the quantity of ice it melts, or the number of degrees to which it heats a certain quantity of water. Thus, it is found that the burning of one pound of good coal melts 90 pounds of ice; of coke, 84 pounds; of wood, 32 pounds; of charcoal of wood, 95 pounds; of peat, 19 pounds. In speaking of the heating effects of combustion, it is specially necessary to bear in mind the different capacities of bodies for heat, or their *specific heat.* Water, for instance, has great capacity for heat, or is very difficult to warm. The same amount of heat that raises the temperature of a pound of water 1°, will heat 30 pounds of mercury to the same extent.

The combustion of fuel is seldom perfect, except in the case of coke, wood-charcoal, and anthracite coal, which are composed of carbon without hydrogen. Common coal consists partly of carbon, and partly of bitumen or pitch. The bitumen also contains carbon, but in combination with the volatile gas, hydrogen; and when heated to a certain degree, it rises or distils off in vapour. If the heat is only about 600°, this vapour is thick and black, constituting *smoke*, and as it cools, it deposits *soot*, which is carbon in fine powder. A greater heat makes the carbon and hydrogen take another arrangement, and become carburetted hydrogen gas—common coal-gas—which is transparent like air, and does not deposit carbon when cold. It is this highly heated gas, combining with the oxygen of the atmosphere, that constitutes *flame.* The pitchy vapour rising from burning fuel is not hot enough to combine with oxygen, unless it come in contact with flame or hot coals. It thus appears that fuel which burns with flame has always more or less hydrogen in it; coke and charcoal, from which the gaseous part has been driven off, burn without flame.

We now proceed to consider the application of the heat thus generated to the warming of dwellings, keeping in view rather the illustration of the general principles that should guide every such application, than entering into constructive details of apparatus.

The great aim, it may be premised, in all plans of warming is, as it is expressed by Dr Arnott, '*to obtain everywhere on earth, at will, the temperature most congenial to the human constitution, and air as pure as blows on a hill-top.*' The obtaining of the desired temperature would be comparatively easy by itself; the difficulty lies in combining warmth with pure air. The various plans hitherto tried may be classed under the four heads of—The Open Fire, Stoves, Gas, Steam and Hot Water.

THE OPEN FIRE.

The first application of artificial warmth consisted, most likely, in lighting a fire of dried sticks and leaves in a grove, a cave, or other natural shelter. When tents or wigwams came to be erected, the fire would be lighted on the middle of the floor, with perhaps a hole in the roof for the smoke to escape by. This primitive arrangement still exists in Central Asia and Siberia, and may even be seen in some of the cabins of Ireland and the Scottish Highlands. The Romans warmed their apartments chiefly by portable stoves or chafing-dishes, without any regular exit for the smoke and fumes; and a brasier of charcoal is still the chief means of lighting sitting-rooms in Spain and Italy, which are in general without chimneys. As late as the fourteenth century, the hearth in Britain continued to be in the middle of the apartment, and the smoke escaped by an opening in the roof, called the louvre (Fr. *l'ouvert*). At last, the fire was placed at the side, in a sort of apartment formed by two projections, within which were placed seats where the warmth might be enjoyed. This recess came gradually to be built in the thickness of the wall, and was thus transformed into the modern chimney.

It is scarcely necessary to remark, that the mode of heating apartments now most prevalent in Britain is by a fire of coal placed in a grate, having a chimney above, through which the vaporised products of the fuel are carried off. There can be no doubt that this glowing open fire has an air of cheerfulness and comfort, which makes it almost an object of worship; yet it is not unattended with certain drawbacks and disadvantages. The greatest of these is the uneconomical use which it makes of fuel. About one-half of the heat produced by a common fire ascends with the smoke; the black part of the smoke itself being an unconsumed part of the fuel. Finally, about a fourth of the heat which is radiated into the apartment is, in ordinary circumstances, carried back by currents into the chimney between the fire and the mantel-piece, and thus lost. It is calculated by Dr Arnott, that only about one-eighth part of the heat-producing power of the fuel used in common fires is realised, all the rest being dissipated into the surrounding atmosphere. Notwithstanding this and other acknowledged evils, the open fire continues to hold its place, partly perhaps from prejudice, partly from real points of superiority over other methods as yet

practised; and the object of late has been, not so much to do it away, as to improve it.

Grates.—One improvement consists in diminishing the quantity of metal in immediate contact with the fuel, and forming the back and sides of the grate of fire-bricks. For the reason given above, this renders the combustion more complete and the yield of heat greater.

Another point deserving attention is the shape given to the chimney-mouth, or recess above the grate. When the sides are square with the back, none of the heat falling on them is given out again into the room. With a view, therefore, to throw out the heat better, the sides, or *covings*, as they are called, are inclined to the back at an angle of about 130°; and sometimes they are made curved and of polished metal, in order that they may reflect the heat without absorbing it. It is questionable, however, if simple brick slabs, placed at the proper angle, do not throw out more heat than the most splendid polished metal plates.

Much also depends upon the shape of the fire-box, or grate, itself. To see the importance of this, it is necessary to attend carefully to the exact way in which an open fire heats a room. It does so almost entirely by the rays of heat that it throws out; and these rays do not warm the air directly; they pass through it like light through glass, just as the hottest rays of the sun pass through the upper atmosphere, leaving it cold enough to freeze mercury. It is only when the rays of the fire fall on the floor, furniture, and walls of the room, that they give out their heat; and it is by coming in contact with these solid heated bodies that the air is gradually warmed. We may thus see the necessity of having a fire lighted and burning brightly for a considerable time before the hour when the apartment is expected to be comfortable.

The law that radiant heat neither affects nor is affected by the surrounding air, also explains the fact that an apartment may feel very cold though the air in it be at high summer heat. A church or other massive stone building in frosty weather may be filled with heated air, and yet retain its chilling effect for many hours. The warmth of the living body is lost in two ways: the film of colder air that touches it receives part of its heat by conduction, and rising up makes room for another film to do the same; a moderately heated body, in cooling, is robbed of about half its heat in this way. The other half is given off in rays, which pass through the air and impinge upon the objects around. These objects are radiating back heat in return; but their temperature being low, the return is small, and the warmer body is colder by the difference. Hence we are chilled by a cold wall or a cold window without touching it, and though the air between us and it may be at 70°.—To return to the shape of the grate.

The chief object is to present as large a surface as possible of glowing fire to the front. With this view, the grate is made long and deep, in proportion to its width from front to back. This principle, however, is carried too far in many grates; the stratum of fuel is too thin to burn perfectly. The bottoms of grates should be solid, instead of consisting of bars; this, which is the usual construction, causes an excessive draught and a waste of fuel. The error may be corrected in an existing grate by placing over the bars a piece of sheet-iron cut to fit.

The practice recently come into vogue of placing grates almost on a level with the floor is a mistake. The floor and the feet of the inmates do not thus receive their due share of the radiant heat.

The chimney-throat, instead of a gulf drawing in a constant wide current of the warm air of the room, and causing draughts from windows and doors towards the fireplace, should just be sufficient to admit the burnt gases and smoke that come directly from the fire, and no more. This is the object of the movable plate in what are called *register-grates.*

It would be endless to attempt to enumerate the various forms of grate constructed, with more or less success, on the above principles. We shall content ourselves with a notice of the smokeless grate invented by Dr Arnott, to whom the subject of warming apartments is more indebted than to any individual since the days of Count Rumford. It comes nearer to the idea of perfection in an open fireplace than any previous contrivance. Its peculiar advantages will be understood from the following description and diagram:

Arnott's Smokeless Grate.—*ab*, *ef*, represent the front bars of a grate in a chimney of the usual construction, *rswu*. The grate has no bottom,

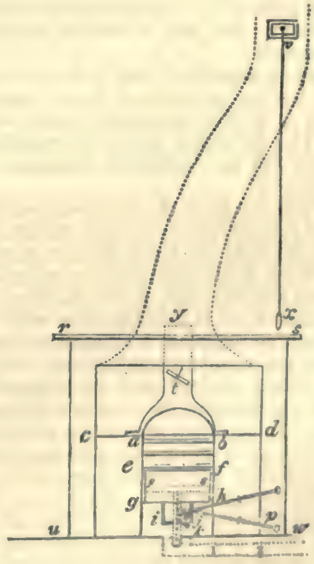


Fig. 1.

and below it is an iron box, open only at top, into which the charge of coal for the day—from twenty to thirty pounds—is put. Any kind of coke or coal may be used. To light the fire, the usual quantity of wood is laid on the surface of the fresh coal at *ef*, and a thickness of three or four inches of cinders or coked coal, left from the fire of the preceding day, is laid over all. 'The wood being then lighted, very rapidly ignites the cinder above, and at the same time the pitchy vapour from the fresh coal below rises through the wood-flame and cinders, and becomes heated sufficiently itself

to become flame, and so to augment the blaze. When the cinder is once fairly ignited, all the bitumen rising through it afterwards burns, and the fire remains smokeless.'

As there is no supply of air but through the bars in front, the box being close underneath, the fire must be gradually raised up as the combustion goes on; and this is effected by having a false bottom, *ss*, in the box, which can be moved like a piston by means of a rod. The rod has notches in it, and, by means of the poker used as a lever, can be raised up and then retained at any height by a ratchet-catch.

'A remarkable and very valuable quality of this fire is, its tenacity of life, so to speak, or its little tendency to be extinguished.' Even after it sinks below the level of the box, it does not go out, but continues to smoulder slowly for a whole day or night, and is ready to burn up actively when the piston is raised.

Another peculiarity of the Arnott grate is the means taken to diminish the proportion of the heat usually carried up the chimney. Of the thick column of smoke that issues from a common chimney-can, only a small fraction is true smoke or burned air; the rest consists of the warmest air of the room, which becomes mixed with the true smoke in the large space usually left between the top of the fire and the throat of the chimney. To remedy this evil is the object of the hood of metal, *yab*, in the diagram, which prevents the entrance of pure air to mix with the smoke. The saving of fuel in this way is said to be from one-third to one-half.

The hood is furnished with a throttle-valve or damper, *t*, having an external index, shewing its position, so as to give complete control over the current. The provision made for ventilation in this fireplace will be considered in another part of the paper.

Even in this, perhaps the most economical form of open fire yet contrived, there is still great waste of the heat actually produced by the combustion. To say nothing of what passes by conduction from the fire itself into the wall, and is mostly lost; the quantity carried off in combination with the hot gases, though no more air is allowed to enter than is necessary for complete combustion, is still great. It deserves being noticed, that the proportion thus carried off is greatest in the case of fuel that burns with flame. Experiment shews that a fire of wood radiates one-quarter of its heat, the rest flying up; while the radiation from wood-charcoal is one-half of the whole heat produced. Every one has felt that a *blazing* fire has far less warming effect than a glowing one. Not that flame has not intense heat in it—more intense even than a glowing fire; but it gives it out only by contact, and not by radiation. It thus appears that any mode of heating that depends upon direct radiation, as the open fireplace chiefly does, necessarily involves great waste of fuel. This can be avoided only by applying the heat on a different principle, which consists in first making the fire heat certain apparatus with considerable surface, which then, by radiation and contact with the air of the apartment, diffuses its heat throughout it. This is the principle of the other methods of warming, which we now proceed to describe. The consideration of methods that combine the two principles, will come most conveniently last.

WARMING BY STOVES.

A *close stove* is simply an inclosure of metal, brick, or earthenware, which is heated by burning a fire within it, and then gives out its heat to the air by contact, and to surrounding objects by radiation. The simplest, and, so far as mere temperature is concerned, the most effective and economical of all warming arrangements, is what is called the Dutch stove; which is simply a hollow cylinder or other form of iron standing on the floor, close at top, and having bars near the bottom on which the fire rests. The door by which the coals are put in being kept shut, the air for combustion enters below the grate; and a pipe, issuing from near the top, carries the smoke into a flue in the wall. If this pipe is made long enough, by giving it, if necessary, one or more bends, the heated gases from the fire may be made to give out nearly all their heat into the metal before they enter the wall; and thus the whole heat of the combustion remains in the room.

The great objection to this form of stove is, that the metal is apt to become overheated, which not only gives rise to accidents, but has a hurtful effect upon the air. It cannot be said to burn it, in the proper sense of the word, for none of its oxygen is abstracted; but it gives it a peculiar odour, which is both unpleasant and unwholesome. This is thought to arise in some measure at least from the hot iron burning the particles of dust that light on it, which particles consist of organic matter, such as wool, wood, &c.

Part at least of the unwholesomeness of air so heated arises from its excessive dryness; it parches and withers everything it touches, like the African simoom. It must not, however, be supposed that this is peculiar to air heated by contact with metal; *air suddenly heated is always unwholesomely dry*. This is an important point in regard to the subject of warming, and requires consideration. The relation of vapour to the air is fully explained in METEOROLOGY, which the reader is recommended to consult in connection with this subject. It may be stated shortly here, that a cubic foot of air, say at 32°, can contain a certain quantity of moisture and no more; but if heated to 80°, it is capable of containing *five* times as much, and has thus become *thirsty*, and drinks up moisture from everything that contains any. Whenever the temperature within doors is much higher than without, the air is in a too thirsty state, and parches the skin and lungs, unless means be taken to supply the necessary moisture. An evaporating pan or other contrivance is an essential part of warming apparatus; it is specially necessary to attend to this during east winds, which are generally too dry even at their natural temperature.

All improvements on this simple and rude form of stove aim at avoiding a high heat in the warming surface, and this chiefly by lining the fire-box with brick, and inclosing it in several casings, so as to enlarge the heated surface. A general notion of these contrivances may be got from the annexed cut (fig. 2), representing the kind of stove called a *cockle*. The fire is burned in a small furnace within the inner case, and the air

is warmed by circulating between the inner and outer cases. When placed in the apartment or hall to be warmed, the outer casing has perforations about the top for the issue of the warm air. For heating churches and similar buildings, the stove is placed in a separate furnace-room, and the warm air is conveyed to the different parts of the building in pipes or flues, while fresh air is drawn to the stove through a channel or culvert leading from outside the building to the openings in the outer casing, where the arrows are seen entering.

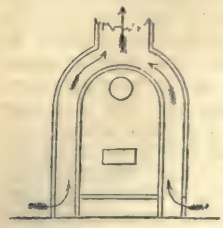


Fig. 2.

The stove invented by Dr Arnott is upon the same principle of an extensive and moderately warm heating surface. For the description, we must refer to the inventor's own treatise on *Warming and Ventilation.* For many years, Dr Arnott has had his own dining-room warmed by such a stove. The fire in winter is never extinguished, and a uniform temperature of from 60° to 63° is maintained by consuming at the rate of about a ton of anthracite in six months.

In Germany and other northern countries of Europe, the stoves are usually built of brick, covered with porcelain. They are of the size of a large and very high chest of drawers, and usually stand in a corner of the room. The fire is burned in a furnace near the bottom, and the heated smoke is made repeatedly to traverse the structure from side to side, along a winding passage, before it reaches the top, where a pipe conveys it, now comparatively cold, into a flue in the wall. The heated mass of brick continues to warm the room long after the fuel is burned. It is generally sufficient to warm the stove once a day. The same quantity of wood burned in an open grate would be consumed in an hour, and would hardly be felt.

Open-fire Stoves.—As a specimen of the numerous plans for combining the advantages of the stove and the open fire, we may take Sylvester's stove or grate, which is thus described in Ronalds and Richardson's *Technology:* 'The fuel is placed upon a grate, the bars of which are even with the floor of the room. The sides and top of these stoves are constructed of double casings of iron, and in the sides a series of vertical plates, parallel with the front facing, are included in the interior, which collect, by conduction, a great portion of the heat generated from the fire—the mass of metal of which these are composed being so proportioned to the fuel consumed, that the whole can never rise above the temperature of 212° Fahrenheit under any circumstances. The sides and top of the stove are thus converted into a hot chamber, offering an extensive surface of heated metal; at the bottom, by an opening in the ornamental part, the air is allowed to enter, and rises as it becomes warmed, traversing in an ascent the different compartments formed by the hot parallel plates, and is allowed to escape at the top by some similar opening into the room.'

Stoves furnished with a series of parallel plates to increase the heating surface and prevent an excessive temperature of the metal, are known as *gill* stoves, from the plates having a resemblance to the gills of a fish. They have recently come into considerable use.

The idea of having an air-chamber behind and around the fireplace, from which warm air would issue into the room, thus saving part at least of the vast amount of heat that is lost by passing through the wall, is not new, having been put in practice by the Cardinal Polignac in the beginning of last century. But the way to carry the principle out to the full would be to have the open fireplace in a pier of masonry standing isolated from the wall, like a German porcelain stove. A very small fire would keep the whole mass mildly heated. The pier could receive any shape, so as to give it architectural effect; and it might either terminate in the room—the smoke, after parting with most of its heat, being conducted by a pipe into the wall—or it might be continued into the story above, where its heat would still be sufficient to warm a bedroom. An Arnott smokeless grate, set in the pedestal of an ornamental column, which might either stand in front of the wall or in a niche in its depth, might be made the *beau-idéal* of comfort, economy, and elegance.

WARMING BY GAS.

When care is taken to carry off the products of combustion by a pipe, and to prevent overheating, gas-stoves will be found economical and pleasant, and capable of being used in situations where a common stove is inadmissible.

In stoves, gas should always be burnt with the Bunsen burner, which is generally employed by chemists when they make use of gas for heating purposes. It consists of a small brass cylinder, or chimney, set over the gas-jet, like the glass of an argand lamp, with openings near the bottom to allow air to enter. The gas being admitted into this before lighting, mixes with the air, and when lighted at the top, burns with a pale-blue flame. The most complete combustion and the greatest heat are obtained in this way. Smoke, properly so called, there is none. Still it must not be forgot that there is burnt air—a cubic foot of carbonic acid, besides a quantity of watery vapour, for every cubic foot of gas used; and therefore, even with the Bunsen burner, these gaseous products should, wherever it is possible, be conducted away.

STEAM AND HOT WATER.

The immediate warming agent in these two methods is the same as in Arnott's and other low-temperature stoves—namely, an extensive metallic surface moderately heated; but instead of heating these surfaces by direct contact with the fire, the heat is first communicated to water or steam, and thence to the metal of a system of pipes. This affords great facility in distributing the heat at will over all parts of a building; and these methods are peculiarly adapted to factories, workshops, and other large establishments. Other advantages are—freedom from dust, and from all risk of overheating and ignition.

Steam.—Steam-warming is generally adopted in establishments where steam-power is used, as the same boiler and furnace serve both purposes.

When steam enters a cold vessel, it is condensed into water, and, at the same time, gives out its latent heat till the vessel is raised to 212°, when the condensation ceases. The condensing vessel is usually a cast-iron pipe placed round the wall of the apartment near the floor. In admitting fresh air into the room, it may be made to pass over this pipe, and thus be warmed. The steam is conducted from the boiler by a smaller tube, which may be covered with list or other material, to prevent all condensation by the way; and the admission of the steam is regulated by a cock within the apartment, means being provided for allowing the air to escape. Where a pipe cannot be laid round the room, a coil of pipe may be formed, or the steam may be admitted into a large vessel or into a hollow statue, forming a steam-stove. Allowance must be made for the expansion of the tubes by heat; and they are so arranged that the condensed water is conveyed back to the boiler. One round of iron pipe, of 4 inches diameter, is quite sufficient to warm each of the large apartments or stories of the printing-office from which the present work issues. It is difficult to estimate the expense of supplying the heat, seeing that the steam happens to be drawn from a boiler which is always in operation for other purposes. Excellent, however, as the process is, it is for many reasons unsuited to private dwelling-houses.

In calculating how much surface of steam-pipe will be sufficient to warm a room, it is customary to allow about 1 foot square for every 6 feet of single glass window, of usual thickness; as much for every 120 feet of wall, roof, and ceiling, of ordinary material and thickness; and as much for every 6 cubic feet of hot air escaping per minute as ventilation, and replaced by cold air.

Hot Water.—Hot-water apparatus was applied as early as 1777 by M. Bonnemain, in Paris, to warm the hot-houses at the Jardin des Plantes, as well as for the artificial hatching of chickens. It was first introduced into England by the Marquis de Chabannes in 1816, and is now used in many large buildings. It is more economical than steam, except where a steam-boiler is required for machinery; and from this and other advantages, it is generally preferred to steam-apparatus. One of these advantages is, that the heat begins to be distributed, in some degree, as soon as the fire is lighted, while with steam-apparatus the whole of the water must be at boiling-heat before any steam enters the pipes.

There are two kinds of hot-water apparatus—high-pressure and low-pressure. In the first, the water is confined, and can be heated to any degree; in the other, it is open to the air, and cannot be heated above 212°. Fig. 3 will explain the way in which water is made to carry the heat of a furnace to any part of a building on the low-pressure principle. *a* is a boiler, from the top of which a tube issues, and, after circulating through the building, re-enters near the bottom. At the top of the circuit there is a funnel, or a small cistern, *c*, by which the tubes and boiler may be kept full.

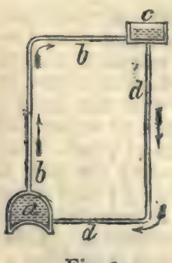


Fig. 3.

When the fire is lighted at the bottom of the boiler, the heated portion of water, being lighter than the rest, rises towards the top through the tube, *bb*, while the colder water from *dd* flows in to take its place. The tube is made to traverse the apartments to be warmed, where it gives out its heat to the air; the returning portion of the pipe is thus always colder, and therefore heavier than the other, so that the circulation is constantly kept up. The warming surface is increased, wherever it is necessary, by coiling the pipe, or by making expansions upon it of various forms, so as to constitute water-stoves.

To avoid the necessity of so large a surface, and such a mass of water as is required at the low temperature the water attains in the pipes of this kind of apparatus, Mr Perkins introduced the high-pressure system. In this the pipe is made comparatively small, but very strong, and is formed into an endless circuit cut off from the atmosphere. The water is heated by making a number of coils of the pipe itself pass through the furnace; and as the whole circuit forms a shut vessel as it were, the temperature may be raised to 300° and upwards, according to the strength of the pipes. This high temperature causes a rapid circulation. A compendious and readily understood specimen of the apparatus, calculated for a house of three stories, is presented in the accompanying engraving. In filling the tube with water, which enters at *b*, care is taken to expel all the air; and at *a* there is an expansion of the tube, equal to 15 or 20 per cent. of the capacity of the whole, which is left empty both of water and air, to allow for the expansion of the water when heated. The arrangement of the pipe may be various: the plan generally followed is to place a considerable coil of it within a pedestal or bunker, with open trellis-work in front, in a convenient part of the room. It may also be made to wind round the room, behind the skirting-board, which, being perforated with holes, will allow of the entrance of the warmed air.

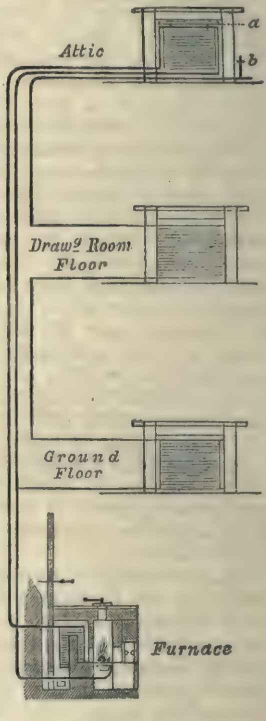


Fig. 4.

This hot-water apparatus is fitted up in various public buildings, warehouses, and gentlemen's houses; and, while sufficiently effective for the desired end, it has been proved to be attended with as few drawbacks as any regulated mode of heating whatever. But there is a great obstacle to its general adoption in its expensiveness. The

temperature also becomes at times so high as to cause a disagreeable odour. Another objection is its liability to burst; though, from the tubes being of malleable iron, such an accident causes more inconvenience than serious danger.

Conservation of Warmth.

The art of warming embraces not only the production and distribution of heat, but the construction of apartments with a view to prevent its escape. The way to effect this—setting aside in the meantime the necessity of renewing the air—is, in the first place, to make the walls, floor, windows, doors, &c. as impervious to air as possible, to prevent the heat from being carried off by currents; and, in the next place, to make them bad conductors of heat. For this last purpose, the walls ought to be sufficiently thick, and, if possible, built of non-conducting materials. Solid iron would make a cold wall; wood a warm one; and in this respect brick or porous stone is preferable to hard stone. But the chief element in a warm wall is that it be *double*, which every wall in effect is, when it is lined by a coating of plaster, kept apart from the wall itself by the laths. The plate of confined air between the two is the most effectual barrier to the passage of the heat outwards that could be contrived. By making iron walls double or cellular, with a lining of plaster, they might be rendered as warm as wished. Windows are a great source of cold, not merely by admitting cold air, but by allowing the heat to pass by conduction through the thin glass. The air of the room that touches the window is robbed of its warmth, and is constantly descending in a cold stream towards the floor. There is thus a cold influence felt from a window, however close it is. This is partly arrested by window-blinds, shutters, and curtains, which check the flow of the air, and retard its carrying power. But a far more effectual plan is to have double windows; either two frames, or double panes in the same frame. The loss of heat by a double window is said to be only one-fourth of that by a single. Double windows are considered essential in countries where the winters are rigorous.

By carrying those principles far enough, we might succeed in well-nigh imprisoning the heat, and thus produce a house of ideal perfection, so far as mere temperature is concerned. But for the habitation of living beings, another condition, seemingly antagonistic to the former, is no less requisite—'air, as free as that on a mountain top.' In general practice, the two hostile conditions are not so much sought to be reconciled as compromised; and then, as usual, neither object is well attained. Circulation of air is got accidentally, through the imperfections of structure in our rooms—through the chinks and bad fittings of the windows, doors, floors, and the uneconomical fashion of our fireplaces. Neither the airing of our houses, nor the art of building them solid and warm, can advance to perfection, until the former be no longer left to chance, but be in every case secured by special apparatus capable of direct control. We now proceed to consider how this is sought to be attained; confining ourselves still to the leading principles, and only noticing a few of the specific plans that have been put in practice.

VENTILATION.

The importance of constantly respiring pure air is more fully considered in the paper on PRESERVATION OF HEALTH. For our present purpose, it will be sufficient to bear in mind the following facts. Fresh air is chiefly made up of two gases, which are everywhere found to be in the same proportion: nitrogen forming about four-fifths of its bulk, and oxygen forming one-fifth. It also contains a very variable quantity of vapour of water, and a smaller but pretty constant quantity of carbonic acid gas (see CHEMISTRY)—namely, 1 part in 2000 by measure. When a portion of this air has been once breathed, it is found to have undergone several changes, which render it unfit to be breathed again. The chief vitiation consists in a portion of the oxygen being abstracted, and nearly as much carbonic acid gas substituted for it, the carbonic acid having been formed by the oxygen uniting with the carbon of the blood. The average quantity of carbonic acid in expired air or breath is found to be 4·3 per cent. by measure. Now this gas, when taken into the lungs, is a poison, and tends to arrest the vital processes. Like other poisons, however, it can be rendered harmless by *dilution*. The small proportion naturally existing in the atmosphere is perfectly innocuous, and may be considerably increased without sensible effect. But it is decidedly prejudicial to breathe for a long time air containing 1 measure in 100 of carbonic acid, and it is considered desirable that the proportion should never exceed 1 in 500. As about 20 cubic feet of air pass through the lungs of a man in an hour, the respiration of one human being thus vitiates hourly about 500 cubic feet of air.

In addition to carbonic acid, expired air contains an undue amount of watery vapour. Minute quantities of animal matters are also exhaled with the breath, which in close, ill-ventilated apartments, form a clammy deposit on the furniture and walls, and, by putrefying, become organic poisons.

A further necessity for the constant renewal of fresh air arises wherever lights are burnt. Every cubic foot of gas consumes the oxygen of ten feet of air, and forms at least one foot of carbonic acid, besides watery vapour, sometimes mixed with sulphurous fumes. The effectual remedy for this is a large glass globe inclosing the light, and having at top a metal tube communicating with the chimney flue.

In an ordinary apartment heated by a common open fire, there is an imperfect kind of ventilation always going on by means of the fire, which draws in through the door, windows, and other apertures, fresh air to supply that consumed by itself, or which the chimney-draught otherwise carries off. This is imperfect in many ways; for one thing, it only operates when there is a fire. It therefore becomes desirable that a regulated mode of ventilation, calculated to be thoroughly and at all times effectual, should be applied to ordinary apartments. It is not less necessary that churches, court-rooms, theatres, and all large halls in which great numbers of persons assemble, should be subjected to a mode of ventilation, regular, certain, and complete. Nor is it unworthy of notice that a regular means of ventilation is

also required in stables, cow-houses, and other places where valuable animals are kept.

Ventilation consists of two operations—the removal of the foul air, and the introduction of fresh. Though neither operation can go on without the other going on at the same time, it is convenient to consider the two separately.

The agents employed in removing the air from apartments are chiefly two: that by which nature effects the ventilation of the earth on a grand scale (see METEOROLOGY)—namely, the draught of ascending currents produced by difference of temperature; and mechanical force, such as pumping. The former is the more common, and is the only one applicable to private houses.

The column of air in the chimney of a lighted fireplace being expanded and comparatively light, exerts less than the prevailing pressure on the air immediately under and about its base. On the principle, therefore, explained in HYDROSTATICS and PNEUMATICS, the air below and around it pushes it up, and flows in to take its place; the velocity of the movement being in proportion to the height of the chimney and the degree of heat. Thus, although it is often convenient to speak of the air being *drawn* or *sucked* into the chimney, the force does not lie in the chimney, but in the greater pressure of the air behind.

Wherever, then, there is a heated chimney, there is a means of removing the foul air. And in rooms moderately lofty and spacious, with windows and other fittings not closer than usual, and a chimney-mouth of the usual width, there is little risk, when there are only a few inmates, of any serious vitiation of the air. The ascent, however, of foul heated air to the top of the room dictates its exit in that direction, rather than low down at the mouth of the chimney. It is conceived by some that the carbonic acid of the breath, from its greater weight, must be chiefly at the bottom of the room; but this is a mistake. The heated breath ascends instantly, because it is, as a whole, lighter than the air around it; and the carbonic acid in it does not tend to separate from it and fall down by its superior weight, but, by the law of the diffusion of gases (see METEOROLOGY), seeks to spread itself equally all over the room, and would do so though it were lying at first on the floor. It is on the principle of the foul air ascending at first to the top of a room that Dr Arnott's ventilating-valve is contrived. The valve may be used to supplement the open-fire draught in small and crowded apartments, and is essential where the fire is burned in a close stove or in the smokeless grate. The valve is represented at *v*, fig. 1. An aperture is cut in the wall over the chimney, as near to the ceiling of the apartment as may be convenient. In this is suspended a valve, capable of opening inward to the chimney, but not in the other direction, by which means a return of smoke is prevented. It operates by virtue of the draught in the chimney. A wire descends to a screw or peg fixed in the wall, by which the opening of the valve may be limited or altogether prevented. This is a far more efficient plan of ventilation than an open window, or an opening in the wall near the roof, leading merely to the outer air; where there is an open fire in the room, such openings rather admit a rush of cold air than let out the foul.

There is generally more or less draught in a chimney even without a fire, from the air within being slightly warmer than that without; and this action might be strengthened by burning a jet of gas within the ventilating aperture at *v*. Where a house is to be built new, some recommend having special ventilating-flues in the walls, separate from, but close to the fire-flues, so that the air may be heated, and an ascending current produced. In weather when fires are not required, the draught can be maintained by gas-jets at the entrances to the vents. This plan of causing a draught by gas is applicable to churches and apartments without fireplaces.

Where a fire is burned for the express purpose of producing a current of air, it is called ventilation by *fire-draught*. The plan has been exemplified with success in mines, where a fire being lighted at the bottom of a shaft, air is drawn off in all directions around, and sent up the shaft; to replace which, fresh air is constantly pouring down other shafts.

Many of our large buildings are ventilated by fire-draught. Fig. 5 shews an arrangement by which a school or church may be ventilated: *aa*, the flooring perforated with holes, through which air, warmed by hot-water pipes, passes to the interior. The ceiling, *bb*, is perforated, leading to a chamber which communicates with a vertical flue, *cc*; which leads to the fireplace of the warming-apparatus, situated at the foot of a flue, *ed*. As the only air which reaches this must pass from *cc*, a constant current is maintained therein, and also through the apertures in the ceiling. Dr Reid exemplified this method, first in his own class-room in Edinburgh, and afterwards in various public buildings, among others, in the temporary House of Commons, erected after the burning of the old house in 1834. The arrangements for warming and ventilating the present House of Commons are a modification of Dr Reid's plan.

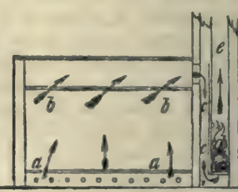


Fig. 5.

In other cases, as at the prison in Millbank, warm air is admitted at the ceiling, and carried off by the draught of a chimney in connection with the sides or lower part of the rooms.

In these last-mentioned instances, the apparatus provides as well for the admission as for the removal of air. In ordinary dwellings, no special provision is in general made as to admission. It is, in fact, not absolutely necessary; for the removal of a portion of the air of a room never fails to secure the entrance of a fresh supply somewhere. Whenever the chimney-draught or other means removes a little of the pressure inside the room, the pressure without forces air through every opening and chink. But this irregular source of supply has various inconveniences. It often requires more force to strain the air in this manner than the draught is possessed of, and then the chimney smokes; it is smoke produced by this cause that is curable by opening the door or window. For these and other reasons, there ought, in all cases, to be a free and legitimate entrance provided for fresh air, so as to give a control over it; and this entrance should be independent of

the windows. It is a much disputed point whereabout in a room the air should be made to enter—some advocating openings for it near the floor, others near the ceiling; and it must be confessed that neither method has yet been rendered unobjectionable. One essential thing is, to prevent the air from rushing in with a strong current, by passing it through minute holes spread over a large space.

But the great difficulty lies in the coldness of the air directly introduced from the outside, whether by the doors and windows, or through channels in the walls; and all such plans of ventilation must be considered as imperfect makeshifts. There can be little doubt that our descendants will look upon them as little less barbarous than we now think the arrangements of the palace of Cedric the Saxon, and the ventilation of Rowena's boudoir, as described in *Ivanhoe.*

The fresh air ought in every case to be warmed before being admitted, or, at least, before being allowed to circulate in a sitting-room. In the smokeless grate (fig. 1), the air is led directly from the outer atmosphere into a channel (1, 2) underneath the hearth, and escaping below the fender and about the fire, is warmed before spreading through the apartment. With stoves and heated pipes, the air should enter about the heated surface; in stoves on the cockle principle, the fresh air, as it enters, is made to pass between the casings of the stove. With an open fire, a very feasible plan is to make the fresh-air channel pass behind the fireplace, and allow the warmed air to escape from concealed openings about the chimney-piece and jambs, or from behind the skirting. In Condy's Ventilating-grate, the firebox is constructed of hollow pieces of fire-brick communicating with the external atmosphere and with the room.

For a house with fireplaces of the usual construction, perhaps the simplest and most effective expedient is to admit the fresh air into the entrance-hall, and there warm it by means of a low-temperature stove or by water-pipes; its passage into the several rooms can then be provided for by regular channels, behind the skirting or otherwise. In America, perforations are frequently made in certain parts of the doors, before which silk curtains are disposed so as to temper the currents. It is almost unaccountable that in this country the plan of warming the lobby and staircase is so seldom resorted to. To say nothing of the comfort thus diffused through the whole house, and the benefit in point of health, especially to weakly constitutions, the economy of the arrangement is beyond dispute. In the sitting-rooms, not more than one-half the usual quantity of fuel requires to be burned in the open fires.

Ventilation by Fans.—The fan-wheel has been for many years used in factories, to which it is particularly applicable, from the readiness with which it can be kept in motion by the engine. It is essentially the same as the barn-fanners; the air is drawn in at the centre of the wheel, and flies off at the circumference by centrifugal force. The fan is placed at the top of a flue, into which branches from all parts of the establishment proceed; and when it is set in motion, it draws off the air from every apartment communicating with it.

Transference of Heat from the used Air to the fresh.—We practise this kind of economy when in cold weather we breathe through the folds of a woollen handkerchief. The breath, raised to the temperature of the blood, leaves a great part of its heat in the handkerchief as it passes through; the cold inspired air absorbs this heat again, and enters the lungs considerably warmed. The same thing is more effectually done by the wire-gauze respirators invented by Jeffrey.

This is essentially the principle of the caloric-engine, or, more properly, hot-air engine, brought forward some time ago by Captain Ericsson of New York; but which is merely a copy of the invention of Dr Stirling of Perth, patented as early as 1816.

Whatever difficulties—or impossibilities, as some maintain—there may be in the way of turning this transferred heat into a fresh source of power, nothing seems simpler, in theory at least, than to economise heat in this manner for the warming of dwellings and similar purposes. The idea originated with Dr Arnott, many years ago,

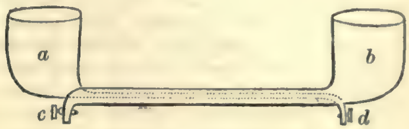


Fig. 6.

who thus illustrates it in the case of water: Suppose *a* a vessel of boiling water, with a thin metallic tube issuing from the bottom, and having a stop-cock at *d*; and *b* a similar vessel of water at freezing, the tube of which is larger, and envelops the other. When both are flowing simultaneously, the hot water, if the tube is long enough, will have lost all its excess of heat before getting to *d*, while the counter-current will have gained all that the other lost. In an experiment with tubes six feet long, the boiling water from *a* issued from *d* at 34°, and the freezing water from *b* issued from *c* at 210°. It is clear that if *a* were a bath, the warm water in it, after being used, might in flowing out be made to heat the cold water from a reservoir, *b*, flowing into another bath below *c*.

It will at once strike the reader how desirable it would be to do the same with the impure heated air which we are obliged to eject from our dwellings. Where the ventilation depends upon the draught of a common chimney, it would seem impossible to bring the entering air in contact with that which is escaping; but where the mechanical force of a pump is employed, nothing seems simpler than to make the two currents run counter to one another for a certain distance in close contact through a system of tubes.

Notwithstanding all the improvements recently effected, it is beyond doubt that this important branch of the art of living is still in a very rude and imperfect condition. A writer in the *Quarterly Review* for April 1866, in a very suggestive article on *Coal and Smoke*, points to the radical error of the existing system, when he remarks that 'in a household fire heat is, as it were, manufactured on a very small scale; and experience has proved that the cost of production of an article has always been inversely proportionate to the scale of its

manufacture.' He accordingly suggests that 'it seems practicable, in a great measure, to supersede domestic fires, and to lay on heat (heated air), or the means of generating heat (low-priced gaseous fuel), to our houses pretty much as we now lay on gas.' The abatement of the smoke-nuisance, and systematic and thorough ventilation, ought to be effected on a similar joint-plan, 'by connecting the chimneys of all the houses with underground culverts, provided at intervals with high shafts, in which, if necessary, the draught upwards might be increased by furnaces.'

Even though such painstaking plans of economising heat might not pay at the present cost of fuel in this country, it is pleasing to think that there is such a resource in reserve. It is not with all countries as with us; and even our stores of coal are not inexhaustible. It is an unworthy, and, in the real sense of the word, an inhuman maxim, that bids us 'let posterity look to itself.' If the absorbing passion for present gain will not let us begin practising economy now, we may at least seek to devise and perfect plans to be in readiness when the necessity comes. It is not uncommon to hear the argument, that before the coals are done, something else will be discovered as a substitute. We are at a loss to imagine what the something is to be, unless it be the ingenuity to make the fuel that is now wasted in a year, last ten; and this we believe to be quite possible.

PREVENTION OF SMOKE.

The smoke arising from the furnaces employed at factories has been long felt as a great nuisance, polluting, as it does, the pure air of heaven, and begriming every exposed object within the range of its influence. In London the smoke-nuisance is now punishable by fine; and in Scotland there is a similar law, applicable to the whole country. Experience has demonstrated that it is not impracticable, with skilful construction of furnaces, and careful management of fuel, to reduce the evil to such small proportions as to be scarcely worthy of notice; but, excepting in those towns where the law has been rigorously asserted, the nuisance continues to be a disgrace to the sanitary condition of our towns, and to our national character for cleanliness. The first conditions for smoke-consumption are—such an arrangement of the furnace as to insure a supply of atmospheric air sufficient for complete combustion, and a judicious disposal of the fuel itself, in order that the vaporised carbon may be brought in contact with the air in a sufficiently hot condition. The first of these depends upon the construction of the furnace, the latter upon the care and skill of the fireman. The fireman who properly attends his fire keeps it pretty equally distributed as an even bed of burning coal over the fire-bars, and when a fresh supply of fuel is required, instead of throwing it in as far as possible over the burning surface, he piles it up near the furnace-door, as in fig. 7, which represents a common furnace, A the fire, B the door, and C the ashpit. The pile of coal, D, being acted upon by the heat, soon gives out its volatile products, and these passing over the intensely hot surface of the partially consumed fuel, are raised to the temperature necessary for combining with the oxygen of the air mixed with them. Thus with careful firing even an ordinary furnace will produce comparatively little smoke. This effect, however, may be heightened by special contrivances in the construction of the furnace. Mr Wye Williams, of Liverpool, has pointed out

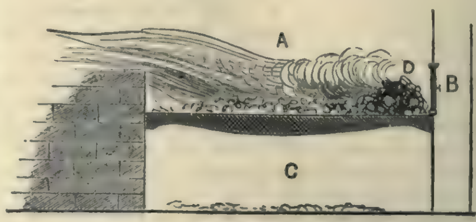


Fig. 7.

great improvements in the construction of furnaces, the chief principle of which is to bring the atmospheric air into contact with the fuel in a heated state, and to make the fire itself heat the air which is coming to supply it. This arrangement will be best understood by the drawing, fig. 8, which represents one of Mr Williams's furnaces under a boiler, *h*. The fire is fed, as usual, through

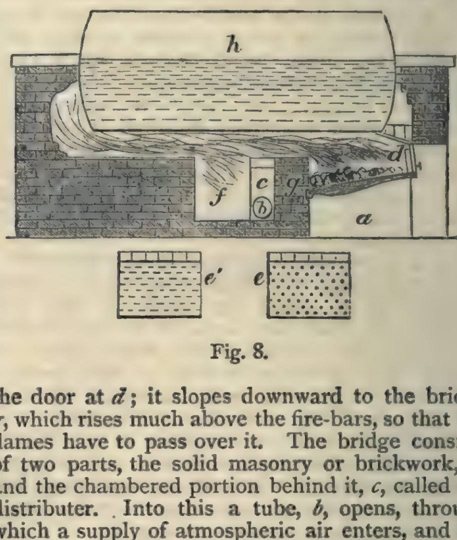


Fig. 8.

the door at *d*; it slopes downward to the bridge *g*, which rises much above the fire-bars, so that the flames have to pass over it. The bridge consists of two parts, the solid masonry or brickwork, *g*, and the chambered portion behind it, *c*, called the distributer. Into this a tube, *b*, opens, through which a supply of atmospheric air enters, and becoming heated, passes through a number of plates with slits, or with perforations, as shewn in *ee'*, into the mixing-chamber, *f*; here the heated air enters into combustion with the carbon in the smoke-laden flame, deprives it of that element, and greatly increases the heat by its combustion. Good as this contrivance is in theory, it does not seem to have come into general use except in modified forms.

Of plans depending upon the slow and regular admission of the fresh fuel by means of machinery, it will be sufficient to notice that of Jukes. His grate-bars are endless chains passing over rollers. and moved forward about an inch per minute, The coal employed is common siftings or screenings, which is heaped on the bars outside the furnace-door, which slides upwards. The door is left a little open, and by passing under it, the small coal is spread uniformly over the bars. The

air is constantly supplied through the bars directly to the fuel while burning, and in this way perfect combustion is obtained. The bars, being slowly moved on, carry the ashes to the ashpit, which lies at the back of the grate. Jukes's apparatus was applied to the furnace of the engine which prints this work in 1848, and has been completely successful; it is rare that a single particle of smoke can be seen issuing from the chimney, and the saving in coal and attendance is decided.

LIGHTING.

Artificial lighting depends upon the fact that solid bodies, when heated to a certain degree, become luminous or *incandescent*. The luminosity begins at the temperature of about 800°; and as the heat is increased, the red passes into a white of greater and greater brilliancy.

Gaseous bodies, however hot, give little light. In order to produce light, we must have a highly heated solid substance. In practice, this is best obtained by burning volatile compounds of carbon and hydrogen. The combustion of the hydrogen produces intense heat, and the particles of solid carbon, before being themselves burnt, become white in the hot gas.

While pure carbon may be used as fuel for producing heat, carbon and hydrogen united, and burning in the shape of flame, produce most light, because the combustion is more rapid, and the heat more intense. Carbon and hydrogen combine in a variety of ways, and produce a numerous class of compounds, called *hydro-carbons*, some of which are solid, some liquid, and others gaseous, but mostly capable of being vaporised by heat. A number of natural products, such as the animal and vegetable oils, tallow, wax, &c. are altogether composed of such compounds, and can be vaporised or distilled without leaving any solid residue. These form the readiest sources of light, because the substances may be distilled or vaporised by the heat of the flame that produces the light, as in the case of a candle.

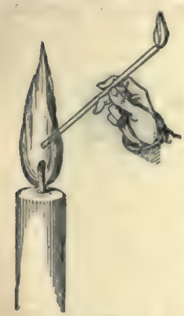


Fig. 9.

Structure of Flame.—The flame of a lamp or candle, or simple gas-jet, consists of a hollow cone, in the centre of which there is no combustion.

The central space appears dark only by contrast with the luminous cone which surrounds it. It consists, in reality, of transparent invisible compounds of carbon and hydrogen, which are constantly rising in vapour from the wick. If a glass tube, open at both ends, be held obliquely in the flame of a candle, with its lower extremity in the dark central space above the wick, it will conduct away a portion of the combustible vapour, which may be kindled like a gas-jet at its upper end, as represented in fig. 9. This dark portion of the flame may be called *the area of no combustion*.

The luminous cone which envelops the dark space is *the area of partial combustion*. The oxygen of the atmosphere penetrates to this depth, but not in sufficient quantity to oxidise or burn both the carbon and the hydrogen; it therefore unites with the hydrogen, for which it has the stronger attraction, and leaves the carbon free. The outer cone is named *the area of complete combustion*, because there the carbon meets with sufficient oxygen to burn it entirely. The light is produced in the area of partial combustion, where the carbon is set free from the hydrogen in the form of solid particles, and is heated to whiteness by the combustion of the hydrogen. The combustion of the carbon in the outer cone, by which it is converted into carbonic acid gas, produces heat, but so little light as to be barely traceable.

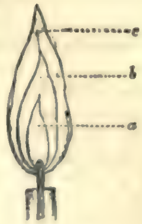


Fig. 10.
a, Area of no combustion.
b, Area of partial combustion.
c, Area of complete combustion.

That carbon exists in a solid state in the white part of a flame, is readily shewn by holding a piece of white earthenware into it, which becomes coated with carbon in the form of soot.

The highly illuminating power of compounds of hydrogen and carbon is thus traced to the fact, that *their hydrogen and carbon do not burn simultaneously, but successively, and in such a way that the one heats the other white-hot.* It is quite possible to make them burn simultaneously; but when they do, the light evolved is very feeble. This is seen in the Bunsen burner alluded to, p. 485.

ILLUMINATION BY CANDLES AND LAMPS.

In principle, these two modes of lighting are the same. The essential parts of a lamp are a vessel containing liquid fat, from which a portion rises gradually by capillary attraction through the wick to the flame. In a candle, the solid fat below the flame is melted into the form of a hollow cup, which forms a reservoir for the liquefied portion, and becomes thus a tallow lamp.

The chief difficulty that attends the use of lamps as a source of light is, to procure the complete combustion of the oil, so as to keep the flame from smoking. The round cotton-wick used in the old simple form of lamp was always attended with smoke and smell. The oils and fats are exceedingly rich in carbon, containing 70–80 per cent. of that element, and only 10–12 of hydrogen. The round thick column, then, of oil-vapour rising from the wick of an old-fashioned lamp, presents too little extent of surface to the air; the oxygen of all the air that can get access is chiefly taken up in burning the hydrogen, and a large proportion of the carbon ascends in the burnt air as smoke. The most essential improvement in this respect is what is known as the Argand burner, from the name of its inventor. In this the wick is in the form of a ring. The flame is thus a hollow cylinder, with a current of air ascending through the inside, so that the burning surface is doubled.

Another part of Argand's improvement consisted in placing a glass cylinder as a chimney over the flame, by which means the flame is steadied and a draught created.

Subsequent improvements have had for their object to deflect the currents of air from their parallel course, and make them strike against the

flame. With this view, glass chimneys are often made to contract a little above the top of the flame.

Another difficulty attending the use of the ordinary animal and vegetable oils in lamps arises from the change of level in the oil. This is sought to be remedied by making the vessel wide and shallow; and in order that it may cast as little shadow as possible, it is disposed in the form of a wide ring round the burner. But the most effectual plan is to have the oil pumped up from the foot of the lamp to the wick by mechanical means. The most perfect mechanical lamp is that of Carcel, a Frenchman, in which the oil is pumped up by clockwork; it is, however, by far too expensive and difficult of repair to be adapted for ordinary use. The French Moderator Lamp is much simpler, and appears to overcome the difficulties of the case. The body of this lamp consists of a cylinder or barrel, the lower part of which contains the store of oil. On the top of the oil rests a piston, which is constantly pressed down by a spiral spring, situated between it and the top of the barrel. Through the piston is inserted a small tube, which passes up to the burner at the top; and the pressure of the spring on the piston causes a constant stream of oil to rise up through this tube and feed the wick. What is not consumed flows over the burner, and back into the barrel above the piston. It is above the piston also that fresh oil is introduced. When the piston has reached the bottom, it is wound up again by a rack and pinion, and a vacuum being thus formed, the oil above it is forced to the under side through a valve kind of contrivance round its edge.

It is obvious that in this machine the flow of oil will be greatest when the piston has been newly wound up, and the spring is at its greatest tension. This inequality is regulated, or *moderated*—hence the name of the lamp—by an extremely ingenious contrivance, which narrows the passage for the oil when the pressure is strongest.

The introduction of mineral oils—known under the various names of paraffin oil, petroleum, kerosene, naphtha, shale oil, &c.—has in a great measure superseded the use of animal and vegetable oils for lighting purposes. The great recommendation of the former is their cheapness. One great difficulty with the mineral oils at first was that, without careful preparation, they are apt to give off inflammable vapours at a low temperature, which give rise to dangerous explosions. This has been obviated by processes of rectification which get rid of the lighter and more volatile ingredients. An oil that gives off an inflammable vapour at a temperature under 120° F. can hardly be considered safe. Paraffin oil from Boghead coal will not form an explosive mixture under 140° F. (See USEFUL MINERALS, p. 389.) It is illegal to store or issue oil forming an inflammable mixture under 100° F. Another difficulty was to make the oil burn without smoke. The kind of lamp found to effect this purpose best was introduced into Great Britain from Germany about 1856, and, with minor improvements, the form is still adhered to. The body of the lamp is a globular-shaped reservoir of glass or stone-ware for the oil, mounted on a foot or pedestal; into this a brass wick-holder is screwed, the wick being raised or lowered by means of a rack and pinion. The peculiarity of the paraffin lamp is a dome-shaped cap surrounding the wick-tube, and having a slit running across it, through which the flame issues. A long glass chimney rests on a ledge or gallery around the base of the cap; and by perforations in the brass an air-chamber is formed below. The chimney causes a strong draught through this chamber, and the cap or dome deflects the current of air, and makes it impinge against the flame as it passes through the slit, thus producing perfect combustion and a white, brilliant light without smoke. The oil is so volatile that the flame has a very slight hold of the wick, so that, if properly burned, six inches of wick will last a year. The demand for these lamps has become so great, especially in America, where gas is expensive, that the manufacture and sale of them forms an extensive business of itself.

A great drawback in the use of the common paraffin lamp is the expense and annoyance attendant on the frequent breakage of the glass chimney. To obviate this, Rowatt and Son of Edinburgh have introduced their patent *Anucapnic* (smokeless) lamp, which dispenses with the glass chimney altogether. Instead of it, a second cap or dome is placed over the ordinary one, leaving a narrow space between the two. As the two cones get hot, a powerful draught is created, and two separate currents of air are directed against the flame, one by the lower cap, as in the ordinary lamp, and the other from between the two caps. The result is perfect combustion, without a chimney. A large glass globe is used to protect the flame from currents of air, as well as to disperse and soften the light. Such a globe is also often used with the ordinary lamp in addition to the chimney, a flange for supporting it being added to the burner. Fig. 11 represents the smallest form of paraffin

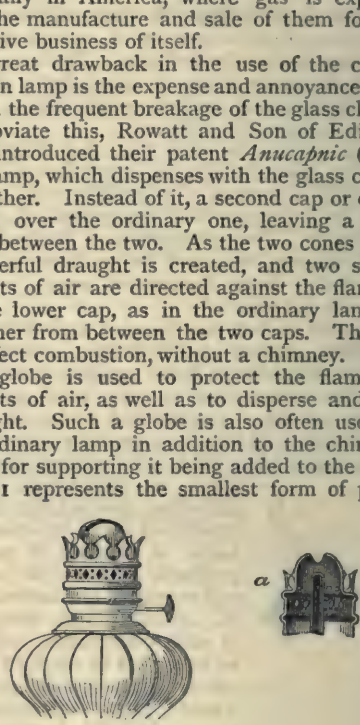


Fig. 11.

lamp. A section of the burner is represented at *a*. The double domed lamp is represented in fig. 12.

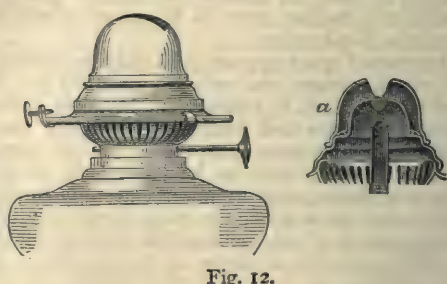


Fig. 12.

Mineral oil thus burned furnishes a satisfactory light, rivalling gas in cheapness (see page 496).

GAS ILLUMINATION.

The existence of an inflammable air, as a natural production, has been known from a period of great antiquity. It was observed to issue spontaneously from fissures in the earth; and has been employed in such situations, as a source of light and heat, both in ancient and modern times. This natural gas is also found in abundance in some coal-mines, where it constitutes the 'fire-damp' so destructive to the miner.

The artificial production of an inflammable air, by distilling coal in a close vessel, is first mentioned in a letter by Mr Clayton, rector of Crofton, Yorkshire, addressed to the Royal Society, May 12, 1688. Though well known to chemists from this time, it was only esteemed as a philosophical curiosity until the year 1792, when Mr Murdoch, an engineer, then residing at Redruth, in Cornwall, prepared coal-gas on a scale sufficiently large to light up his own house and office. In 1798, he was engaged to put up his apparatus at the manufactory of Messrs Boulton and Watt, Soho, near Birmingham, where he continued to experiment, with occasional interruptions, until the year 1802. It does not appear, however, that much attention was excited by these first efforts at gas-lighting, except among a very few scientific individuals, until the general illumination at the peace of Amiens afforded an opportunity for a more public display. On this occasion, the front of the manufactory was brilliantly lighted up by the new method, and it at once attracted the wonder and admiration of every one who saw it. 'All Birmingham poured forth to view the spectacle; and strangers carried to every part of the country an account of what they had seen. It was spread about everywhere by the newspapers; easy modes of making gas were described; and coal was distilled in tobacco-pipes at the fireside all over the kingdom.'

In the course of a few years from this date, gas-lighting, especially for streets and public buildings, began to spread over the kingdom. The chief contributor to the success of the movement was Mr Clegg, who invented the hydraulic main, the wet-lime purifier, and the wet gas-meter. Its progress in dwelling-houses was at first retarded by the injurious effects of the impurities it contains in its crude state. But science has shewn how most of these may be effectually removed, and well-made gas is now almost free from noxious properties.

The use of gas-lighting in cities and towns is now pretty general over the world. Where coal is scarce, it is prepared from resin, oil, refuse fats, &c. Oil-gas was at one time extensively used in Great Britain, but though it is of very superior quality, the comparative economy of coal-gas made the manufacture be given up.

The organic substances that form the great bulk of coals are compounds of the elements carbon, hydrogen, and oxygen, with small proportions of sulphur and nitrogen. When coals are submitted to a red-heat in close vessels or retorts—a process known as *destructive distillation*—the whole of these organic elements, except a portion of the carbon, are volatilised or drawn off in vapour. Coal-gas thus distilled out is not a definite chemical compound, but a mixture of many unlike substances—consisting chiefly of, first, coal-tar, a very complex mixture of various compounds of carbon and hydrogen; second, ammonia combined with carbonic acid and sulphuretted hydrogen; third, light and heavy carburetted hydrogen, in combination with sulphuretted hydrogen, carbonic acid, carbonic oxide, and certain combinations of sulphur and carbon, which it is the business of the manufacturer to separate as completely as possible from the gas before it is sent out for distribution and consumption.

Of the uncondensed and permanent gases, the most important are two hydro-carbons. The first—namely, olefiant gas—is composed of 4 atoms of hydrogen with 2 atoms of carbon. Its specific gravity is ·979, common air being considered as unity, or 1·000. When pure, it burns with a dense white light, combining with three times its bulk of oxygen, and producing carbonic acid and vapour of water.

The second—namely, light carburetted hydrogen—is composed of 4 atoms of hydrogen, combined with 1 atom of carbon. Its specific gravity is ·553. It is this gas which is met with in coal-mines, and which forms an explosive mixture with atmospheric air. It burns with a yellowish flame, combining with twice its bulk of oxygen.

The relative quantities of these gases differ according to the quality of the coals and the mode of manufacture; there is always much more of the light compound than of the heavy; but the quality of a gas depends upon having a high proportion of the heavy, as it gives a much brighter light; the proportions of the heavy amounting to 10 or 12 per cent. of the volume in the *best* qualities, usually manufactured from cannel-coal; and from 4 to 6 per cent. in gas made from Newcastle coal. There also remain traces of the other hydro-carbon vapours uncondensed, which, by their large proportion of carbon, add to the whiteness of the light. Of the other gases forming the mixture, the carbonic oxide and the free hydrogen are of no use, but being once formed, are difficult to be got rid of. They burn, adding to the heat of the flame, but not to its light, and yielding watery vapour and carbonic acid.

Manufacture of Gas.

The various kinds of coal differ greatly in the extent to which they are volatilised by distillation. In some, as much as 70–80 per cent. of coke—consisting of carbon and earthy matter—remains in the retorts; in general the coke is about 50 to 55 per cent. of the weight of coal. The coals best adapted for the manufacture of gas are the compact kind, known in England by the name of cannel, and in Scotland by the name of parrot coals. The English caking coals, of which a great part are obtained in the neighbourhood of Newcastle-on-Tyne, are, however, from their cheapness and the superior quality of the coke which remains after distillation, more extensively used than any other.

English caking-coal yields 8000 to 10,000 feet of gas per ton, of illuminating power equal to 12 to 15 candles; cannel-coal yields from 10,000 to 14,000 feet per ton, and illuminating power from 16 to 35 or 40 candles—the standard of comparison being the light from a sperm-candle consuming 120 grains sperm per hour, and the gas-burner consuming at the rate of five cubic feet per hour—

all observations being corrected to these generally recognised standards. As a general rule, the parrot coals which yield the greatest quantity of gas, yield also gas of the highest illuminating power.

As the value of coal-gas depends on the proportion of olefiant gas and heavy hydro-carbons which it contains, great attention is required in heating the retorts; if their temperature be too low, the tar and liquor are increased in quantity, and the gas diminished in quantity. If the temperature be too high, the olefiant gas is decomposed, and light carburetted hydrogen formed.

While different parts of the apparatus necessary for producing, purifying, storing, and sending out the gas are capable of many variations in size, form, and construction, the order in which they come into use is almost invariable. First, there are the *retorts*, *ascension* and *dip pipes*, and the *hydraulic main;* then the *tar-well* and *condenser*, the exhauster, the washer or scrubber, the *purifier*, the station-meter, the *gas-holder*, and the governor—the parts printed in italics being indispensable. Besides the above, valves of various forms and water-traps are employed. The annexed wood-engraving shews an arrangement common in small gas-works.

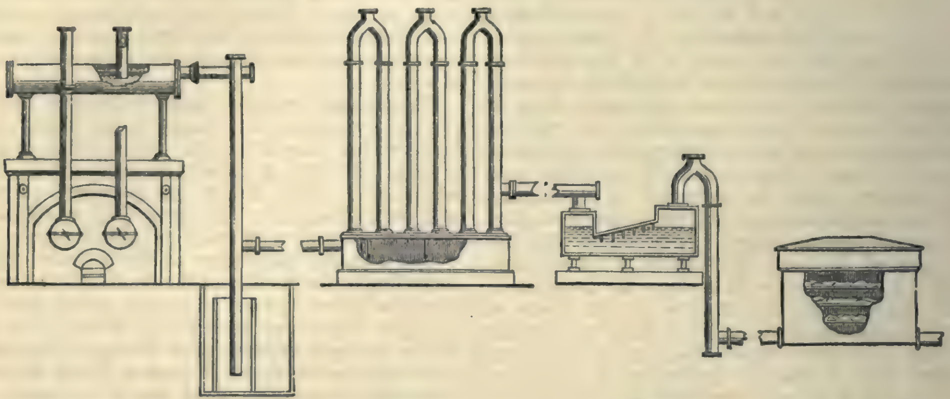


Fig. 13.—ELEVATION OF GAS-WORKS.

The retorts are generally made of fire-clay; cast-iron retorts, once common, are now seldom to be met with. They are made D-shaped, cylindrical, kidney-shaped, and elliptical. The sizes most common are from 6 to 9 feet in length, and from 12 to 20 inches in diameter. The retort is built horizontally into an arched oven, in such a manner as to be equally heated throughout from a furnace beneath. From one to seven retorts, and sometimes a greater number, are set in the same oven. The mouth-piece of the retort is of cast-iron, and projects outwards from the front wall of the oven sufficiently far to admit between the mouth and the front of the oven an opening, to which the ascension-pipe is connected for conveying the gas to the hydraulic main. When the coal to be distilled is introduced into the retort, the mouth is closed tight with a lid.

The hydraulic main is a large horizontal pipe made of thick plate or cast-iron. It is first about half-filled with water, which in the course of a short time is entirely displaced by the liquid product of distillation. The dip-pipes, which are the continuation of the ascension-pipes, dip into the liquid through which the gas bubbles up into the upper portion of the hydraulic main. The gas and liquid come off at the end of the hydraulic main, and flow together till they reach the tar-well, into which the liquid, by its greater gravity, falls. The liquid consists of tar and ammoniacal water. These are withdrawn from the tar-well, and become the raw material from which other products are manufactured. From the tar, naphtha, pitch-oil, pitch, and coke, together with some of the most beautiful dye-stuffs and delicate essences, are obtained; and from the water, salts of ammonia, so valuable in agriculture and the arts, are prepared.

The simplest form of condenser consists of a series of upright pipes, connected in pairs at the top. These are erected upon a horizontal chest, the top of which has an opening into the bottom of each upright pipe. Immediately under each arch pipe a plate descends from the top of the chest, and dips into the liquid with which the chest is partly filled. In this way the gas is prevented from passing through the chest horizontally, and compelled to traverse the whole series of pipes, the extensive surfaces of which serve to radiate the heat from the cooling gas into the atmosphere, and bring it down to about 50°, at which temperature it is found that the gas, in passing out of the condenser, has left entrapped therein the great bulk of condensable vapours with which it was charged in its journey from the retorts—these consisting of light tarry matters, ammoniacal compounds, tar-oils, and water.

The exhauster, when used, is a species of pump, and serves the purpose of relieving the retorts of the resistance or pressure, created in the passing of the gas through the apparatus, and in raising the gas-holders. The use of the exhauster is attended with other important advantages.

At this stage of the process, the liquid products have been separated from the gaseous. A portion of the ammonia and the sulphuretted hydrogen

and carbonic acid have still to be removed. To remove the ammonia, the washer or the scrubber is used. In the washer, the gas is forced to pass through water to a depth of several inches, or through a solution containing an ingredient with which the ammonia will combine. The scrubber, which may be used instead of the washer, is an upright vessel, in which the gas is made to pass through brushwood, or layers of small stones, or coke, through which water may be made to percolate.

There are two kinds of purifiers—the wet and the dry. Either may be used separately, or they may be used in succession. Lime is the purifying material which is most effective; a preparation of the oxide of iron, however, is rapidly coming into general use. Lime is used in the wet purifier in the form of cream of lime, through which the gas is made to pass. The dry purifier is a square or oblong vessel containing a series of perforated trays, on each of which a layer of dry slaked lime is spread. The lime absorbs the sulphuretted hydrogen, a portion of the ammonia, and the carbonic acid. When saturated, it is removed, and the vessel is refilled with fresh material. The refuse lime is extensively used as a manure. When the oxide of iron is employed as the purifying material, the preparation is spread in the same manner as the lime, but to a much greater thickness. When, by the absorption of sulphuretted hydrogen, the oxide of iron has become sulphuret of iron, it is taken out, and by exposure to the atmosphere, it is reconverted into oxide, and can be used again and again. After passing the purifier, the gas, now fit for use, is measured by the station-meter, and conveyed to the gas-holder.

The gas-holder is an inverted cylindrical vessel of sheet-iron, placed in a tank of cast-iron, stone, or brick, filled with water. A pipe ascends from the bottom of the tank through the water, to admit the gas to the space between the surface of the water and the crown of the gas-holder. Another pipe descends through the water and the bottom of the tank, for the issue of the gas to the main-pipe. The water is for the purpose of retaining the gas within the vessel. The pressure or force imparted to the stream of gas issuing from the retorts and exhauster, raises the gas-holder, and the weight of the gas-holder, or such part of it as is not taken off by balance-weights, impels the gas through the pipes. Gas-holders are constructed of all sizes up to 200 feet in diameter, and are made to contain quantities up to two and a half millions of cubic feet. In large establishments, telescopic gas-holders are used, and economy of space and cost is thereby effected—two concentric gas-holders being contained in one tank. Before reaching the main-pipes, the pressure of the gas is regulated by the governor, which acts like that of the steam-engine.

Distribution of Gas.

The distribution of the gas from the gas-holder is effected in cast-iron pipes called *mains;* the pipes branching from the mains to supply gas to dwelling-houses or manufactories are called *service-pipes.* The pipes have, or should have, an inclination to the main, and the main itself should incline towards the gas-work. For watery vapour is present in small quantity in the gas; being condensed into water in the pipes, it naturally collects in the lowest part, and at last interrupts the continuous flow of gas, so as to cause a flickering of the flame in the burners. Where the proper inclination cannot be attained, an entrapping box or vessel is placed at the part where liquid is apt to collect, so that it can be removed from time to time as it accumulates.

The quantity of gas charged for by gas-companies was at one time regulated by the number and kind of burners employed, and the time they were allowed to burn, and this is still the case as regards the lighting of streets; but this was found to be a most uncertain and unsatisfactory method of guessing the consumption by any individual. It is now obviated by the use of *meters,* of which there are two kinds, the *wet* and the *dry.* The wet-meter consists of a hollow case of iron, containing an inner cylinder or drum, so constructed, that the gas passing through it, by the pressure it receives at the gas-work, causes it to revolve on an axis; each revolution allows a known quantity of gas to pass through the water, with which the outer vessel is partially filled, to the exit-pipe; and as the revolutions are registered by wheel-work and an index, the quantity of gas consumed is indicated with considerable accuracy. The gas-company charges the consumer according to the quantity indicated. This meter is, however, liable to have the water frozen in severe weather, and requires to be frequently replenished with water. To remedy this, various 'dry-meters' have been contrived, but none have yet come into general use.

Burning of Gas.

There is one important fact in the burning of gas, which is equally true of animal and vegetable oils. When a given quantity is burnt in a large flame, a greater amount of light is obtained than when the same quantity is burnt in a smaller flame. Hence one large lamp or gas-jet is better than three or four burning the same quantity in the same time. The cause of this becomes apparent by considering what takes place when a jet of gas is turned down to the lowest point. Here the white light altogether disappears, and only a blue flame remains; the small body of gas as it issues becomes mixed and diluted with air, and the whole is perfectly consumed, as in the Bunsen burner, without any of the carbon becoming solid and incandescent. On gradually admitting more gas, a white speck first appears in the middle of the blue, and this speck—the area of imperfect combustion—goes on increasing not only in absolute size, but its proportion to the area of perfect combustion becomes greater as the whole flame is enlarged. The limit to this economy is the quantity that can be burnt without smoke. This difference between large and small flames does not hold in burning paraffin oil.

The *gas-burners* most used are the single conical jet, the bat-wing, and the union or fish-tail jet. In the bat-wing, the gas issues from a slit across the head of the burner. The union-burner is pierced with two holes, so that the two streams of gas impinge on each other, and produce a flat flame. Metal burners are exceedingly liable to rust, and become useless; but there is a patent burner, made of a silicious composition, which lasts for years without deterioration.

Bude Burner—Bude Light.—The Bude burner

consists of two, three, or more concentric Argand burners, each inner one rising a little above the outer. The *Bude Light* depends upon introducing oxygen into the centre of the flame, instead of air, as in the common Argand.

The *Lime-ball Light*, sometimes called the *Drummond Light*, is produced by directing the flame of a mixture of oxygen and hydrogen against a piece of lime. The flame is itself pale, but the intense heat it communicates to the lime makes the latter give out a light rivalling that of the sun. When gas is passed through naphtha, it becomes saturated with naphtha vapour, which, being exceedingly rich in carbon, greatly increases the illuminating power of the gas.

ELECTRIC LIGHTING.

So great progress has recently been made in the methods for producing and regulating the electric light, that keen public interest in the question of its availableness for general purposes has been awakened. For the fundamental truths of electricity and the cognate subjects, the reader is referred to Vol. I. of this work, at page 257 and following pages. Every circuit offers resistance to an electric current flowing through it, and is in consequence heated. If a small portion of the circuit is made of very high resistance, the heat generated in that portion may be sufficient to make the material there so hot as to become luminous. This is the essence of all electric lighting. The part of high resistance may be a thin strip of a solid conductor, as in Swan's, Edison's, and Maxim's so-called *incandescent* lights; or it may be gaseous, as in the familiar Geissler vacuum tubes and the ordinary *arc* electric lights, of which Siemens', Jablochkoff's, Brush's, Serrin's, and Jamin's may be cited as examples. For practically useful lighting, a strong current is a necessity. Originally this was obtained from a large number of voltaic cells; but these were found so troublesome and costly to keep in good condition, that the electric light remained long a scientific curiosity for lecture-room or laboratory. Faraday's discoveries, however, indicated a new method of producing currents; and the great recent improvement in the construction of magneto-electric machines has quite changed the aspect of the problem of electric lighting. All these machines depend upon the induction of currents in coils moving in the vicinity of magnets, or more generally in any magnetic field however produced. The direction of the induced current depends upon whether the coils are moving from a weaker to a stronger or from a stronger to a weaker region of the magnetic field. In the earlier forms of magneto-electric machines, the coils were made to rotate rapidly in front of permanent steel magnets. More widely employed now are the more recent dynamo-electric machines, or simply *dynamos*, in which electro-magnets are substituted for the permanent steel magnets. The soft iron cores of the electro-magnets never wholly lose their magnetism. Hence the rotation of the coils in their vicinity gives rise at first to a very feeble current, which is directed through both the external circuit and the electro-magnet coils, thereby increasing the magnetisation of the cores, and so intensifying the original induced current. The current and the magnetisation thus act and react upon one another, growing steadily until they have each reached a maximum, which depends on the rate of rotation of the coils and the resistance of the whole circuit. The current so produced may be continuous and in one direction, or discontinuous and in rapidly alternating directions, according to the manner in which the contacts are adjusted at the terminals of the coils. The rotation of the coils is usually effected by a steam or gas engine, so as to obtain a rapidity of motion sufficient to produce a strong enough current.

In electric lights of the arc type the current passes through the air between two pieces of carbon which are attached by wires to the terminals of a Gramme, Siemens, Bürgin, Brush, or other machine. In order to allow the current to work up to its maximum strength, the carbons must first be brought into contact, and then withdrawn to the required distance. If the distance is too great, the resistance in the circuit is made too high, the current ceases to flow, and the light is extinguished. Hence every practically useful light is supplied with an automatic regulator, which keeps the carbons apart as long as the current is flowing, and brings them into contact again if through any accident the current is broken. By its means also the carbons are kept at the necessary distance apart, in spite of their inevitable dissipation under action of the intense heat to which they are subjected. The carbon *from* which the current passes wastes away much faster than that *to* which the current sets. Hence, in Jablochkoff's electric candle, which has the carbons side by side, separated by a strip of a non-conducting material, an alternating current is used, so that both carbons waste away equally. In Werdermann's light there is no appreciable waste on the upper carbon, which is a comparatively broad plate, against which the lower thin pencil-shaped carbon presses. This form of light is one in which the subdivision of the electric light, long an insuperable difficulty, has been very successfully accomplished. For ordinary domestic purposes, however, the arc light is in general too brilliant to be of any real use, and is limited to the lighting of streets, squares, railway stations, large halls, and lighthouses. More suitable for ordinary house illumination are the incandescent lamps of Swan, Edison, and Maxim, which differ only in the mode of preparation. They all consist of specially prepared thin carbon filaments, which become incandescent under action of the traversing current. To reduce their dissipation to a minimum, they are inclosed in hermetically sealed vacuum globes, through the bottom or top of which the platinum terminals are led to the outside. Such lamps are worked with alternating currents, otherwise the carbon filament would tend to thin out at the positive end, and ultimately break. Theatres, lecture halls, and large steamers have already been most successfully lit up with Swan's lamps, which are unsurpassed for their beautiful and peculiarly mild light.

Faure's accumulator, an improved form of Planté's secondary battery, has recently been applied as the source of energy in electric lighting, and may in certain circumstances supersede the magneto-electric machine.

SUPPLY OF WATER—DRAINAGE—BATHS.

AMONG the complicated arrangements of civilised life, there are few of higher importance than those which relate to the command of water. Whether for dietetic and domestic purposes, for the bath, or for carrying away the corrupting refuse of our towns and cities, a liberal supply of good and wholesome water is an indispensable requisite.

Water is one of the primary wants of human life, no less essential than air and food; hence the great importance that has always been attached to the means of its supply. In the earliest records of civilisation, we read of the digging of wells, and of quarrels about the possession of them. The 'Pools of Solomon,' near Bethlehem, which remain now almost as perfect as when they were built, were connected with a scheme for supplying Jerusalem with water. In Assyria and Persia, from the earliest times, water has been conveyed to towns from astonishing distances in open channels or canals, and in subterranean tunnels or *kanats*. In Egypt, also, and in China, gigantic works for conveying water, both for domestic use and for irrigation, have been in existence from remote antiquity. Nor were these undertakings confined to the eastern hemisphere; we have evidence of the existence of kindred works in pre-Christian America. The ancient city of Mexico, which was built on several islands near the shore of the lake, was connected with the mainland by four great causeways or dikes, the remains of which still exist. One of these supported the wooden aqueduct of Chapoltepec, which was constructed by Montezuma, and destroyed by the Spaniards when they besieged the city. Hydraulic works on a great scale had also been executed by the Incas of Peru.

AQUEDUCTS.

Of all the ancient nations, the Romans paid the greatest attention to the supply of water, and carried the construction of *aqueducts* to the greatest perfection and magnificence. In the original sense of the word (*aquæ ductus*, a duct or conductor of water), every leader or channel of water would be an aqueduct; and while, technically speaking, the word is generally used to signify a tunnel or culvert constructed of masonry or brickwork, in which the water flows by a gradual descent, and is distinguished on that account from a pipe, in which the water can be led over undulating country, still the word is generally popularly applied more to bridges constructed for the purpose of carrying canals and other waters across valleys.

Rome at first depended upon water drawn from the Tiber and from wells; it was to Appius Claudius, about three hundred and twelve years before the Christian era, that the Romans were indebted for the improvement of bringing superior water from a distance by means of aqueducts; and for several centuries after his time, additional works were constructed, as the necessities and luxuries of the city demanded. The *Aqua Appia* was only eleven miles long, but some of the subsequent ones were about sixty miles: that built by the Emperor Claudius (51 A.D.) was forty-six miles, of which nine and a half were on arches; and it discharged 97,000,000 gallons in twenty-four hours. One of these aqueducts was formed of two channels, one above the other; the most elevated being supplied by the waters of the Tiverone (Anio Novus), and the lower one by the Claudian Water. It is represented by Pliny as the most beautiful of all that had been built for the use of Rome. The Aqua Marcia, Aqua Julia, and Aqua Tepula entered Rome by one and the same aqueduct, divided into three ranges or stories, each of which supported its own independent channelway.

In general, the conduits, or water-courses, were built of stone, rough or hewn, and occasionally of bricks, and in either case cemented by the finest-tempered mortar. Some were of a square form, paved, and covered with flagstone or tiles; others were arched over, as shewn in the accompanying cut; and some were throughout of an elliptical form. This conduit, or stone-pipe (*c*), if we may apply such a term, was conveyed through hills by tunnels, and across valleys upon arcades, consisting sometimes of double and even triple tiers of arches. In general, these arches supported only one water-course; but occasionally each tier had its own conduit. Having arrived at their destination, the waters were received in reservoirs, and conducted by leaden pipes, or by stone grooves, into private cisterns, or dispersed throughout the cities by means of public fountains, which were often adorned with all the magnificence and allegorical allusion of ancient architecture. These structures were under the charge of a public functionary; and it is from the treatise of Sextus Julius Frontinus, who was inspector of the aqueducts of Rome under the Emperor Nerva, that we derive most of our information respecting the water-works of the imperial city.

Fig. 1.

About 100 A.D. there were nine aqueducts, which, 'it has been calculated, furnished Rome with a supply of water equal to that carried down by a river thirty feet broad by six deep, and flowing at the rate of thirty inches a second;' which is equal to a quantity of 27,000 cubic feet per minute, or 243,000,000 gallons per day (Smith's *Dictionary of Greek and Roman Antiquities*). Another calculation makes the daily supply 300,000,000 gallons. The number of aqueducts was subsequently

augmented to fourteen. Three of them are still serviceable, and modern Rome is more copiously supplied, perhaps, than any other city.

The system of aqueducts was also introduced into those countries that owed allegiance to the mistress of the world; in Greece, Italy, Spain, and Gaul, many were erected. That at Nîmes was perhaps the oldest of these provincial aqueducts; it traversed a most diversified district, piercing hills and crossing valleys. At the place where it crosses the Gardon, it is termed the Pont du Gard; it is 300 yards in length, and is composed of three ranges of arches, one above the other, to the height of 160 feet.

Of the use of the aqueduct in recent times, three instances are alone worthy of notice—the *Lisbon*, the *Croton* at New York, and the aqueduct from Loch Katrine to Glasgow. The first of these, completed in 1738, is about three leagues in length; near the city, it is carried over a deep valley for a length of 2400 feet, by a number of bold arches, the largest of which has a height of 250 feet, and a span of 115. The Croton Aqueduct, which conveys the waters of the Croton river for a distance of thirty-eight miles to the city of New York, is one of the greatest undertakings of modern times. It was commenced in 1837, and finished in 1842, and is calculated to discharge upwards of 60 million gallons in twenty-four hours! The whole cost, including the arrangements for distribution in the city, was about twelve millions of dollars. As the magnificence of aqueducts depends upon the height and number of arches requisite to carry them across valleys, it may give some idea of that under consideration, when it is stated that Haarlem River is crossed by fifteen arches, seven of which are of 50 feet span, and eight of 80 feet, the greatest height being 150 feet from the foundation to the top of the mason-work. No essential change occurs in the form of the channel-way from the fountain reservoir on the Croton to the receiving reservoir on the island of New York—a distance of thirty-eight miles—except in crossing Haarlem River, to reach the island, and in crossing a deep valley on the island, where iron pipes are used.

The Loch Katrine Aqueduct, which was finished in 1859, is of the same nature—from its commencement at Loch Katrine to the Mugdock Reservoir, it is 25¾ miles long, 13 of which were tunnelled, 3¾ miles are iron piping across valleys, and the remaining 9 miles are open cutting and bridges. Where the ground was cut open, the surface was restored after the aqueduct was built. The built and tunnelled part is capable of passing 50 millon gallons per day, and the pipes across the valleys, which are four feet diameter, deliver about 24 millions. The total cost of the aqueduct was £468,000, or an average of £18,000 per mile. The Ganges Canal is another very important piece of hydraulic engineering, in the course of which there are several very large and extensive bridges and aqueducts.

Compared with the hydraulic works of the Romans, it must be confessed that the efforts made to supply modern cities, in Europe at least, are insignificant enough. Some years ago, a covered conduit, 80 miles long, was constructed, which conveys 8 million gallons of pure chalk spring-water from the sources of the Dhuis, in Champagne, to Paris; and more recently, the chalk springs of the Vanne, calculated to yield 22 million gallons a day, have also been brought to Paris, a distance of 104 miles.

In 1867, a Royal Commission was appointed for the purpose of inquiring into the condition of the water-supply of London; and numerous different schemes were laid before them. The first on the list was that of Mr Bateman, who proposed to utilise the high drainage-grounds of North Wales, which supply the head-waters of the river Severn, the drainage area of which is 204 square miles. The water was to be conveyed in an aqueduct, and discharged into large reservoirs, proposed to be constructed about ten miles north-west of London. The total distance would be a little over 180 miles, and the aqueduct was intended to be able to carry 230 million gallons per day. The total cost of the scheme, which was to be brought in in four different instalments, was estimated at £11,400,023. The committee reported against the scheme, on account of the objections of its great distance, which would be certain to prove a fatal one, as the whole metropolis would be reduced to complete want in the event of accident occurring to the aqueduct, more especially during the hostile occupation of the country in case of war.

The next scheme considered was that proposed by Messrs Hemans and Hassard, who proposed to supply the metropolis with water from the lakes of Cumberland and Westmoreland. The distance from London is 240 miles, area of district 230 square miles, and the available quantity of water 287 million gallons per day, and the estimated cost £13,500,000. The remarks of the Commissioners on this scheme were to the same effect as in the case of Mr Bateman's; and they concluded by remarking, that they held it to be erroneous in principle that any one town or district should take possession of a gathering-ground geographically belonging to another, unless it can be clearly shewn that circumstances render such a step justifiable. The Commissioners came to the conclusion, that the Thames water has many good qualities, which render it peculiarly suitable for the supply of the metropolis, and which give it in some respects a superiority over the soft waters usually obtained from high gathering-grounds. It is well aërated, has good keeping qualities, and is perfectly safe as regards action on lead and iron.

In 1869, and again in 1871, a bill was before parliament to bring the water of St Mary's Loch into Edinburgh, a distance of forty miles. But a strong opposition having arisen, on a variety of grounds, among the inhabitants of Edinburgh, it was thrown out by the committee of the House of Lords.

SOURCES OF WATER.

The primary source of all *fresh* water is rain (see METEOROLOGY). Rain-water, as it is formed in the upper regions of the atmosphere, is the purest that nature supplies; but in its descent, it carries down with it whatever impurities it comes in contact with, which, in the neighbourhood of towns, are numerous, consisting of various gases, together with soot and other floating particles, organic and inorganic. Rain-water has a strong affinity for organic impurities—that is, the corrupting ingredients derived from vegetable and animal

bodies, which are diffused over every surface in the vicinity of living beings; hence, when collected from the roofs of houses, it has a tendency to rapid putrefaction. Being free from saline ingredients, it is excellent for washing, but is not pleasant to drink.

But if we resort to a district the surface of which is destitute of vegetation, and remote from the pollution of towns, we may obtain surface-water containing little organic impurity.

Rivers.—The water obtained from streams and rivers is in part what has flowed immediately from the surface, and in part the water of springs. In any case, a considerable amount of contact with the ground has taken place, and, in consequence, saline and organic matter is liable to be dissolved in a greater or less degree. The extent of the impregnation, as well as the kind of material dissolved, will depend on the rocks and strata of the river-basin.

River-waters, besides the qualities they derive from their primitive sources, are apt to contain mud, decayed leaves, the exuviæ of fish, and other matters in suspension, and are thus deficient in the clearness and transparency so essential to the satisfaction of the eye in a drinking-water. Moreover, the water partakes of the extremes of summer and winter temperature. But the great objection to water from rivers is their general pollution from the manure used upon the land, sewage, and manufactures, so that there are now few rivers left from whose lower course a supply could be taken for domestic purposes.

The existence of springs is owing to the fact of rain-water, after being absorbed by an open stratum of rock or earth, through which it is allowed to percolate, coming in contact with some water-tight or impervious stratum, consisting either of rock or clay, by means of which its downward passage is arrested and diverted laterally, so as to find an exit at the surface of the ground at a lower level, either through gravelly material, or some fissure in the rock.

The slow percolation through the interstices of a gravelly layer, or the crevices of rocks, is the cause of the mineral impurities which distinguish the water of springs. At the same time, this slow action most effectually rids the water of any organic impurities contracted at the surface. Air, too, is largely taken in by compression along with the saline matter of the rocks, and the temperature of the interior is imparted to the whole mass; hence it happens that springs of moderate depth represent the average temperature of a climate. Very deep springs are of a higher temperature. The qualities that recommend water to the eye and to the palate belong in a pre-eminent degree to spring-water: it is clear, sparkling, and cool, and is totally free from the offensive taint so common in all other waters, as well as devoid of the animalcules generated by organic impurity.

QUALITY OF WATER.

Perfectly pure water is hardly to be found; rain-water, and even artificially distilled water, are only approximately so. The impurities of water exist either in the form of solid particles, or in a state of solution, and may be considered under the heads of Mineral Matter in Suspension, Mineral Matter in Solution, and Organic Matter.

Mineral Matter in Suspension.—When running water passes over a loose bottom, it carries the finer particles of sand and earth along with it, and the quicker its flow, the larger are the particles that it can keep afloat. If the water comes into a condition of perfect stillness, the particles in suspension gradually sink to the bottom—the heaviest first, and the others in succession. Particles of clay are the most difficult to separate from water by mere subsidence; as they are in a state of finer division than particles of lime, silica, or other minerals. Besides earthy matter, compounds of iron and lead are also in some circumstances present in a solid state, and may be got rid of by filtration.

Mineral Matter in Solution.—Spring-water, which is generally clear and sparkling, holding no solid matter in suspension, is seldom without a large amount of dissolved mineral matter, sometimes as much as 2 parts in 1000, commonly from 1 in 1000 to 1 in 20,000. River and surface water also contains more or less dissolved minerals.

Organic Matter.—The great bulk of the solid matter held in solution in ordinary waters consists of salts; that is, combinations of acids with various bases (see CHEMISTRY). The saline bases are chiefly soda, potash, lime, and magnesia. The most material are the salts of lime and magnesia, as they are the causes of what is called 'hardness' in water, which we shall speak of more particularly afterwards. The most important salt of lime is the *bicarbonate*, which is derived from chalk or limestone. Chalk or limestone is a *carbonate* of lime—that is, a compound of lime with one equivalent of carbonic acid—and is almost insoluble in water; but when water containing an excess of carbonic acid—as is the case with spring-water especially—passes over limestone, it gives it a double dose of carbonic acid, and converts it into bicarbonate, which is soluble. The waters having bicarbonate of lime for their chief impurity are familiarly spoken of as the chalk-waters.

The other salt of lime often present in water is the *sulphate* or *gypsum*. The important distinction between the bicarbonate and the sulphate lies in the fact, that the first, the bicarbonate, may be in great part precipitated, or thrown down in a solid form, by boiling; whereas the second, the sulphate, cannot be so precipitated.

Apart from its hardness, it has been made a question whether water containing salts of lime is injurious or beneficial to the human constitution. The evidence led before the Royal Commission above alluded to went to prove that there is no reason whatever to suppose that the hardness of the Thames water, which averages about 15°, would be in the least degree prejudicial to health. Some eminent chemists have contended that a moderate quantity of carbonate of lime is not only harmless, but that it is actually useful in supplying material for the bones of men and animals. Considering, however, the much larger quantities of carbonate of lime taken in our solid food, such an additional source of supply would seem to be unnecessary. Still it remains to be shewn whether, when large quantities of water are drunk, those waters which contain the smallest quantities of mineral ingredients may not dissolve and take away more from the body than harder waters, and whether there should be any cause for preference on these grounds.

It may also be a question whether, from the better keeping qualities of waters of a moderate degree of hardness, from their general better aëration and greater freshness, and from their less solvent power, such waters are not the best for drinking purposes. Perfectly pure water does not exist in nature. All spring and river waters contain more or less mineral ingredients; and it is only in limited mountain districts, where hard and non-calcareous rocks prevail, that water is found approaching a nearer standard of purity. That the use of these purer waters is more conducive to health, is without proof; but as far as the mere taste is concerned, there can be no doubt that water of a moderate degree of hardness is much more palatable and agreeable than the mawkish discharge from soft-water districts. The greater power of soft water of dissolving and taking up impurities, such as the colouring matter of peat, is another objection to it. To this may be added its unmistakable action on lead; which, however, from causes to be afterwards stated, is not so fatal an objection as it at first seems. Putrefactive decomposition appears also to occur less rapidly in hard than in soft waters, and hard water is more easily preserved for a short time in reservoirs and tanks without deterioration.

With regard to magnesia, its salts are well known to act as powerful medicines when taken in large doses, and, it may be presumed, are not altogether without effect in the small quantities existing in ordinary magnesian waters. A foreign physician has made the observation, that magnesia is the characteristic ingredient of waters in the districts where the diseases called *cretinism* and *goitre* abound.

Of salts of *soda* and *potash*, the principal is common salt, or the muriate of soda. Sulphate of soda (Glauber's salt) occurs along with the muriate in the salt-springs of watering-places as well as in the sea-waters. None of all these salts have any effect on the hardness. In the case of sea-water, which is very hard, the effect is not due to common salt, but to the lime and magnesian salts dissolved in it; were it not for these, sea-water would be perfectly suitable for washing, although not for drinking. The Artesian-well water of London contains a large amount of alkaline salts, chiefly of soda; in one case, as much as 42 grains a gallon. Such water is extremely soft for washing purposes, and well adapted for cookery; but it is doubtful if so great an amount of alkali habitually imbibed be not injurious to the bodily system.

Salts of *iron* in considerable quantity make what are technically named *chalybeate* waters, which belong to the medicinal class. When the iron exists in the spring as carbonate, which is the most usual case, on exposure to the air, it is changed into the peroxide, and falls down in the form of an ochery precipitate. Salts of iron give an inky taste to the water, and a yellowish tint to linen washed in it.

Hardness in Water.

Hardness in water consists of two kinds, temporary and permanent. Perfectly pure or soft water, when exposed to contact with chalk or carbonate of lime, is capable of dissolving only a very minute quantity of that substance, one gallon of water, in weight equal to 70,000 grains, taking up no more than two grains of carbonate of lime. This earthy impregnation is said to give the water 2° of hardness. But waters are often found containing a much larger quantity of carbonate of lime, such as 12, 16, or even 20 grains and upwards in the gallon. In such cases, the true solvent of the carbonate of lime, or at least of the excess above 2 grains, is carbonic acid gas, which is found to some extent in all natural waters. But this gas may be driven off by boiling the water, and the whole carbonate of lime then precipitates in consequence, or falls out of the water, with the exception of the 2 grains, which are held in solution by the water itself. The gas-dissolved carbonate of lime gives, therefore, temporary hardness, curable by boiling. An artificially prepared hard water, containing 13½ grains of carbonate of lime to the gallon, was observed to decrease from 13·5 to 11·2° of hardness merely by heating it in a kettle to the boiling-point. Boiling for 5 minutes reduced the hardness to 6·3°, 15 minutes to 4·4°, 30 minutes to 2·6°, and 1 hour to 2·4°. Other salts of lime, such as sulphate of lime, are generally dissolved in water without the intervention of carbonic acid gas, and therefore remain in solution, although the water is boiled.

The quality of hardness in water is commonly recognised by the difficulty experienced in washing, and by the amount of soap necessary to form a lather. It occasions an enormous waste of soap, extra labour, and a corresponding tear and wear of clothes. The hardening matter contained in 100 gallons of spring-water, drawn from wells or borings in the chalk strata, will destroy thirty-five ounces of soap—that is, the first thirty-five ounces of soap added to this quantity of the water will disappear without forming any lather, or having any cleansing effect. Soap is a compound, formed of an alkali (soda or potash) joined to an oily acid. When a salt of lime, then, is present in the water, the lime decomposes the soap, and combines with the oily acid to form a lime-soap, which is insoluble, and has no detergent properties.

The most usual hardening ingredients are the salts of lime. Every lime-salt whatsoever hardens water and destroys soap in proportion to the lime present. Salts of magnesia are hardening salts, but not in a regular proportion to the quantity, there being some irregularities in their action. When a magnesia-salt is present along with a lime-salt, the magnesia acts rather as a curdler of the soap than as a destroyer. Salts of iron also produce hardness. Salts of soda and potash have no hardening effect.

The late Dr Clark of Aberdeen devised a scale of hardness which is now generally employed in the chemical description of waters, in which each degree of hardness represents the presence of one grain of carbonate of lime in solution in each gallon. The process consists in the addition of a solution of soap of a certain standard strength to a certain quantity of the water under examination, and the amount necessary to form a lather determines the degree of hardness of the water.

Next to washing, the deleterious consequences of hardness are felt in various culinary operations, especially in the furring of boilers and cooking utensils, and in the infusion of tea; and the presence of much sulphate of lime in water makes

it unsuitable for cooking vegetables, owing to the tendency of that salt to form an insoluble compound with their legumine. In the brewing of pale ale it is necessary to use water that is permanently hard from the presence of sulphate of lime; but sweet ales and porters are produced better from soft waters, as they extract a greater amount of matter from the malt. It may be stated generally, that for the purposes of washing and cooking, a water of less than 6° is soft, but above this point the hardness becomes objectionable. At 8°, the water is moderately hard; at 12°, it is very hard; at 16°, the hardness is excessive; and much above this, it is intolerable.

To make these observations more intelligible, we may mention a few instances of known waters, with their place in the scale. In Keswick, the water is under half a degree of hardness; in Lancaster, it is 1½°; and in Manchester, 2°. The water of the Dee at Aberdeen, which is used for the supply of the town, is 1¼° of hardness. The water of Loch Katrine is of remarkable purity, having only two grains of solid matter of all kinds in the gallon, and 1° of hardness. The waters of the Welsh mountains, from which it was proposed to supply London, have on an average less than 2°. The river Clyde, which formerly supplied Glasgow, is 4½°, and may also be reckoned a soft water. The Thames at London, as well as the New River, is about 14°, while many of the tributaries of the Thames rise as high as 16°; but being all chalk-waters, they may be materially softened by boiling. Springs from the chalk commonly range from 16° to 18°; but particular springs are to be met with in some parts of the world four or five times as hard, from the presence of bicarbonate of lime. The water of the Treasury pump in London has from 50° to 60° of hardness.

Lead in Water.—Injurious effects have frequently arisen from the contamination of water with lead, derived from leaden pipes and cisterns. Some kinds of water are known to act powerfully on a leaden surface, and others scarcely at all; but the qualities and circumstances on which the action depends have never been satisfactorily determined. Distilled water, and soft lake and river waters in general, act most decidedly, but by no means in proportion to their softness. The presence of air in the water seems one essential condition, and light also increases the action. The conditions which determine the character of water as regards its action on lead have hitherto been involved in much obscurity, notwithstanding that they have repeatedly been the subject of investigation. The government Commission of 1851, on the water-supply of the metropolis, established the fact, that the presence of dissolved oxygen, and the absence (?) of more than 3 volumes of carbonic acid in 100 volumes of water, are among the conditions necessary to cause the water to attack lead. The result of experiments on this subject proved that the presence of a minute quantity of phosphoric acid, such as could be got by momentary contact with animal charcoal while passing through a filter of that material, completely prevented the softest water acting on lead, without at the same time sensibly increasing its hardness. Even although a soft water like that of Loch Katrine attacks lead powerfully, both while in a bright and also in a tarnished condition, it does not seem necessarily to endanger the lives of the community who use it, as, although the process may go on considerably at first, the protecting film which soon coats the surface of the inside of pipes and cisterns seems to prevent further attacks. This is known to be the case at Manchester, where the water acts slightly on new pipes; but the action soon ceases, and no evil effects are ever recorded as resulting from its use. The reason why Loch Katrine water acts on lead, and the water of St Mary's Loch does not do so, although of very nearly the same degree of hardness, is, that the solution of peat or moss, to which it owes its yellow tinge, has been discovered to have the curious effect of preventing its action on lead. The truth of this is easily tested by pouring distilled water (which, in its pure condition, would attack lead almost instantaneously) over a piece of peat; this water, after being left in contact with the peat for a few hours, will be found not to act on lead in the least. In experiments of this class, the bottle containing the lead and water should not be completely closed, as the free ingress of air is necessary to complete the test satisfactorily. Still, there are opposing facts to shew that this protective action is not always to be relied on; and that water that has passed through any considerable length of lead pipe, or stood for some time in a short one, or in a cistern, should never be used without care; a ninth part of a grain of lead per gallon has been known to derange the health of a whole community.

Organic Impurities.—The contamination of water by vegetable and animal substances takes place in various ways. The most obvious and abundant source of this class of ingredients is the sewage and refuse of towns; and next in order may be ranked the contact with soils rich in organic matter. Among organic impurities may be classed offensive gases, such as carburetted, sulphuretted, and phosphuretted hydrogen; vegetable fibres in a state of rottenness; putrefying products of the vegetable or animal kingdoms; starch, muscular fibre, &c.; urea and ammoniacal products; vegetable forms—algæ, confervæ, fungi, &c.; animalcules — infusoria, entomostraceæ, annelidæ or worms, &c. Water falling on a growing soil, and running off the surface to lie in stagnant ponds, is in very favourable circumstances for being tainted with vegetable and animal life. The surface-water of a district overgrown with peat-moss has usually a peaty flavour, as well as a dark yellowish colour. The infusion of peat does not breed animalcules, being a strong antiseptic; but it is an objectionable ingredient, nevertheless. Lime removes the peat most effectually, but there is both expense and risk in applying it. If fine clay is mixed with peaty water, shaken up, and allowed to settle, the yellow tint disappears entirely, being carried down by the particles of clay during subsidence. It is perhaps doubtful whether any specific unwholesomeness can be justly attributed to peat-water. The inhabitants of Stornoway in Lewis, and Lerwick in Shetland, have no other supply but that from a peaty district, but no complaints are heard of deterioration of health in consequence of its use.

Chalk-water, which, as it issues from a spring, is perfectly free from organic matter, has a source of contamination within itself. When exposed to light and air, the duplicate dose of carbonic acid that keeps the chalk dissolved, becomes

decomposed; and the carbon of the decomposed acid gives rise to a green vegetation, which soon acquires an offensive marshy smell. Water should never be allowed to stand in tanks without roofs to protect it from the effect of the sun's rays, as, before many days, even though there may be a current passing through it, a rank green vegetation is certain to commence. This is more particularly observable in the waters derived from the New Red Sandstone, which is used in Liverpool, where green plants commence to shew themselves in a very short time.

Organic matter in a state of putrefaction forms one of the worst possible kinds of contamination in water. Wells in proximity to graveyards are very often found to be contaminated by the infiltration of decomposed organic particles, which are in reality a deadly poison.

It is a common notion that *every drop of water teems with life;* but this is a mistake. Deep wells, and spring-water in general, contain little or no living organic matter. Consequently, it is quite possible to obtain a liquid perfectly free from animalcules and vegetation. The presence of living creatures, vegetable or animal, discernible either by the naked eye or by the microscope, is a proof of organic taint in the water, and is one of the tests of this kind of impurity. With respect to rain-water, Dr Hassall states, in his evidence before the General Board of Health: 'I have made several examinations of rain-water immediately after its descent to the earth, obtained in both town and country, and can confidently assert that it does not, in general, contain any form of living vegetable or animal matter.' The conditions necessary for the development of vegetation and animalcules over and above the presence of matter for them to feed on, are *air*, *light*, and *stillness*. With regard to the probable effects on health of living creatures contained in water, Dr Hassall's observations are worthy of attention: 'All living matter contained in water used for drink, since it is in no way necessary to it, and is not present in the purest waters, is to be regarded as so much contamination and impurity—is therefore more or less injurious, and is consequently to be avoided. There is yet another view to be taken of the presence of these creatures in water—namely, that where not injurious themselves, they are yet to be regarded as tests of the impurity of the water in which they are found.'

In wholesome natural waters impounded in reservoirs or lochs, the vegetable growth consists mainly of fresh-water algæ, which adhere to and grow on stones in the quiescent parts where there is little current, and where the stones do not roll over each other, but are stationary: specimens of them are to be found in every Highland loch, wherever it is sufficiently sheltered to permit of their growth. Water-fleas, of which the principal kinds are the *Cyclops quadricornis* and the *Daphnia pulex*, are found in most lochs, where they feed on the fresh-water algæ. They are very delicate organisms, and a very little alcohol added to the water kills them, and if the temperature of the water rises even to 100°, they die at once.

Means of Purifying Water.

In all water contaminated by inorganic matter, especially in running water, a process of spontaneous purification is continually going on. Some of the noxious matter is removed by fish and other animal life, and a further quantity is absorbed by the growth of aquatic vegetation; but, in addition to these abstractions, important changes are effected by chemical action. The organic compounds dissolved in the water are of very unstable constitution, and very easily decomposed. The great agent is oxygen, and the process is considerably hastened by the motion of the water. Now, as such waters always contain naturally much oxygen dissolved in them, the decomposing agent is ready at hand to exert its influence the moment the matter is received into the water. Were it not for this beneficent provision, a stream once polluted would continue so through its whole course. In the case of streams passing through populous districts, the contamination goes on at a rate far beyond the power of natural purification; but by means of it, streams that receive only a moderate degree of contaminating matter in their course are kept in a tolerable state of purity. It is chiefly owing to this process that the present water supply of London, which is taken from the Thames at various points above Teddington Lock, and thus washes a populous and cultivated area, is not so excessively contaminated as is commonly supposed, although it is still far from being a desirable water.

The mechanical impurities of water, or the solid particles rendering it muddy or milky, may in most cases be removed by mechanical means. The two processes for this purpose are *subsidence* and *filtration*. The effects of subsidence are strikingly seen in the case of rivers that pass through lakes. Take, for example, the Rhone, which enters the Lake of Geneva of the colour of pease-soup, while it issues from the other end clear as glass and blue as the sky.

In constructing an artificial filter on a large scale, a basin is formed, having the floor nearly level, but slightly inclining towards a centre line, and made water-tight by puddling the bottom and sides with clay. On the floor is laid a series of layers of gravel, coarse at first, and getting gradually finer upwards; next, a layer of slate-chips or sea-shells; then one of coarse sand, on which is placed the actual filtering layer of fine sand. The depth of this layer is from twelve to thirty inches, that of the entire mass from four to six feet. The water being admitted gently on the top of the sand, sinks down, and is conducted by a series of channels, generally of tile-pipes, into the main drain. A filter in a clean state will pass from twelve to eighteen vertical feet of water in twenty-four hours. The solid matter intercepted does not penetrate more than three-fourths of an inch into the sand, so that, by removing a very thin film from the surface, the filter is again clean. What is scraped off the top, is capable of being washed and put again to use.

The cleansing power of sand can hardly be accounted for on the theory of mere mechanical interception. Though there is no chemical action, strictly speaking, there is no doubt that the attraction of adhesion is at work—a power that plays a greater part in natural processes than has generally been assigned to it. Some substances manifest this adhesive attraction more strongly than sand, and have, therefore, still greater efficacy as filters; though practically, and on the large scale,

sand is the most eligible. Powdered charcoal has long been known as a powerful filtering medium, attracting and detaining especially organic matter. Animal charcoal, or that derived from burning bones, is still more efficacious than wood charcoal. A filter of animal charcoal will render London porter almost colourless.

According to recent researches, it would seem that loam and clay have similar properties, and may be made available as filters. Professor Way states that 'they have powers of chemical action for the removal of organic and inorganic matters from water to an extent never before suspected.' The filthiest liquids, such as putrid urine and sewer-water, when passed through clay, dropped from the filter colourless and inoffensive. The clay used was that known as pipe-clay. The great objection to the use of clay for filtering is the difficulty of getting the water to pass through it, otherwise it would be an excellent substitute for sand; but, as mentioned above, dirty or coloured water, when mixed with clay and shaken up, becomes pure when the particles of clay are allowed to subside.

Filters for domestic use will be noticed in the number on HOUSEHOLD HINTS.

Softening of Water rendered Hard by Chalk—Clark's Process.—This is one of the most beautiful applications of science to the arts of life that could perhaps be named. We extract the inventor's own account of it, as given in a paper read before a meeting of the Society of Arts:

'In order to explain how the invention operates, it will be necessary to glance at the chemical composition and some of the chemical properties of chalk; for while chalk makes up the great bulk of the matter to be separated, chalk also contains the ingredient that brings about the separation. The invention is a chemical one for expelling chalk by chalk. Chalk, then, consists, for every 1 lb. of 16 oz., of lime, 9 oz.; carbonic acid, 7 oz.

'The 9 oz. of lime may be obtained apart, by burning the chalk, as in a lime-kiln. The 9 oz. of burnt lime may be dissolved in any quantity of water not less than 40 gallons. The solution would be called lime-water. During the burning of the chalk to convert it into lime, the 7 oz. of carbonic acid are driven off. This acid, when uncombined, is naturally volatile and mild; it is the same substance that forms what has been called soda-water, when dissolved in water under pressure.

'Now, so very sparingly soluble in water is chalk by itself, that probably upwards of 5000 gallons would be necessary to dissolve 1 lb. of 16 oz.; but by combining 1 lb. of chalk in water with 7 oz. additional of carbonic acid—that is to say, with as much more carbonic acid as the chalk itself contains—the chalk becomes readily soluble in water, and when so dissolved, is called bicarbonate of lime. If the quantity of water containing the 1 lb. of chalk with 7 oz. additional of carbonic acid, were 400 gallons, the solution would be a water of the same hardness as well-water from the chalk strata, and not sensibly different in other respects.

'Thus it appears that 1 lb. of chalk, scarcely soluble at all in water, may be rendered soluble in it by either of two distinct chemical changes—soluble by being deprived entirely of its carbonic acid, when it forms lime-water, and soluble by combining with a second dose of carbonic acid, making up bicarbonate of lime.

'Now, if a solution of the 9 oz. of burnt lime, forming lime-water, and another solution of the 1 lb. of chalk and the 7 oz. of carbonic acid, forming bicarbonate of lime, be mixed together, they will so act upon each other as to restore the 2 lbs. of chalk, which will, after the mixture, subside, leaving a bright water above. This water will be free from bicarbonate of lime, free from burnt lime, and free from chalk, except a very little, which we keep out of account at present, for the sake of simplicity in this explanation. The following table will shew what occurs when this mutual action takes place:

AGENTS.		PRODUCTS.	
Bicarbonate of lime in 400 gallons......	Chalk...........16 oz. with Carbonic acid 7 oz.	= 16 oz. of chalk	= 2 lbs.
Burnt lime in 40 gallons of lime-water.............................9 oz.		= 16 oz. of chalk	

'A small residuum of the chalk always remains not separated by the process. Of 17½ grains, for instance, contained in a gallon of water, only 16 grains would be deposited, and 1½ grains would remain. In other words, water with 17½° of hardness, arising from chalk, can be reduced to 1½°, but not lower.

'These explanations will make it easy to comprehend the successive parts of the softening process.

'Supposing it was a moderate quantity of well-water from the chalk strata around the metropolis that we had to soften, say 400 gallons. This quantity, as has already been explained, would contain 1 lb. of chalk, and would fill a vessel 4 feet square by 4 deep.

'We would take 9 oz. of burnt lime, made from soft upper chalk; we first slack it into a hydrate, by adding a little water. When this is done, we would put the slacked lime into the vessel where we intend to soften; then gradually add some of the water in order to form lime-water. For this purpose, at least 40 gallons are necessary, but we may add water gradually till we have added thrice as much as this; afterwards, we may add the water more freely, taking care to mix intimately the water and the lime-water, or lime. Or we might previously form saturated lime-water, which is very easy to form, and then make use of this lime-water instead of lime, putting in the lime-water first, and adding the water to be softened. The proportion in this case would be one bulk of lime-water to ten bulks of the hard water.'

It is of importance that the lime-water—that is, the softening ingredient—be put into the vessel first, and the hard water gradually added, because there is thus an excess of lime present up to the very close of the process. Instead of lime-water, the lime itself may be put at once into the vessel, and some of the water to be softened gradually added to dissolve it. The softened water thus obtained has no action on lead pipes or cisterns, as many soft waters have. One ton of burnt lime, used for softening, will produce three and a half tons of precipitate. The present water-supply of the metropolis, if subjected to Clark's process, would deposit about fifty tons of chalk daily.

The process was in operation on a large scale for several years (1854-1861) at Plumstead, near

Woolwich, where 600,000 gallons daily were operated upon with the most satisfactory result. These works are now given up, though for reasons quite apart from any failure in the process. But numerous water-works have since been erected (some of them quite recently) by Mr Homersham, C.E. London, for supplying water from the chalk springs, softened by Clark's method; for example, at Castle Howard, seat of the Earl of Carlisle; at Caterham, Surrey, for the supply of Caterham, Warlingham, and several neighbouring towns.

Clark's process is not confined in its effects to softening: it has a decided influence as regards organic impurities; for it not only removes the active source of corruption which exists in all chalk-water, as above explained, but the precipitated chalk carries down with it a large proportion of such organic matters as may be already present. Several calico-printers in Lancashire have had Clark's process in use for several years, for the improvement of the quality of the water employed in their works.

In order to prevent the action of soft waters on lead pipes, they have been made with an inside lining of gutta-percha, and also of tin, but the use of such preservatives has become by no means general.

Conveyance, Storage, and Distribution.

We need not enter into a description of the engineering operations connected with the conveyance of water from its source to the town to be supplied, beyond noticing, that when the source is below the level of the houses, steam or other power is necessary to lift or force the water to the necessary height; while in the case of the source being higher than the place where the supply is to be delivered, the water is conducted, should the contour of the country be favourable, either in a channel or culvert with a continuous descent, as in the ancient aqueduct, or, should the undulating nature of the track render the use of an aqueduct impossible, cast-iron pipes following the inequalities of the surface must be employed. The annexed diagram represents an outline of this mode of conveyance; where *a* is a lake or reservoir situated

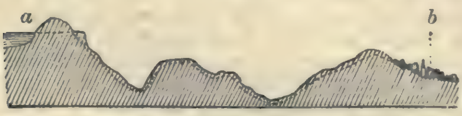


Fig. 2.

in a mountainous district, and *b* a town separated by several miles of irregular country; the course of the pipes is indicated by the dotted line, and the pressure of the water at *a* suffices to make the water rise at *b* to a height nearly equal to that of the head. In many cases, both principles are employed, the water flowing for the most part in a gently sloping conduit, tunnelled through hills where necessary, and being carried through valleys in tubes descending and ascending—an inverted siphon, as it is called. The Croton Aqueduct, which supplies New York, is carried across the Manhattan Valley, upwards of 100 feet deep, in this way. The Glasgow supply from Loch Katrine flows mainly in a sloping channel carried through tunnels and over bridges; but there are four miles of iron pipings across valleys.

The extent of the storage in reservoirs depends on the nature of the source of supply. In utilising the waters of a river or stream, the capacity of the reservoirs depends on the variations in its flow: as, if the discharge were uniform, or nearly so, throughout the year, there would be no use in having storage at all; and in like manner, if the winter floods are very great, and the stream in summer very small, the amount of storage should be very great; the object being to store up the excess which is flowing in the river in the wet season, and deliver it out for use when the natural discharge of the river in summer is under the requirements of the district to be supplied by it.

The reservoirs should be deep, so as to prevent vegetation; and the distributing or service reservoirs should be roofed, to protect them from the contaminations always to be found in the atmosphere surrounding populous places, as well as from the action of the sun.

In distributing water over a town, two different methods have been adopted, known respectively as the *intermittent* and the *constant* systems of supply. On the intermittent system, water is laid on once a day, or once in two or three days, as the case may be, and fills a tank attached to every separate house, and from this tank the water is drawn off as required. The feeding-pipe of such a tank or cistern is provided with a ball-cock (see fig. 3), which ingeniously shuts off or admits the supply, as the cistern may be full or empty. On the constant system, no tank is absolutely needed, except for the supply of water-closets, but the house-pipes are kept constantly charged. The intermittent supply was until lately employed everywhere in the metropolis; but it is universally admitted that the other system is vastly superior in every respect. The disadvantages of the intermittent practice have been strongly set forth in all the recent official Reports on sanitary improvement: the expense of the erection and repair of cisterns, the trouble requisite to keep them clean, the contamination of the water by the neighbourhood of sources of pollution, the frequent waste of water that occurs, the difficulties imposed on the poorer class of tenements where cisterns are not provided—are a few of the objections urged against this mode of supply.

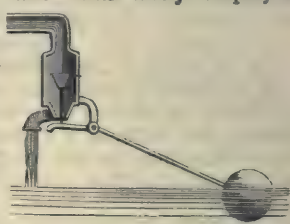


Fig. 3.

One important advantage arising from the constant system is the ease with which water can be had in time of fires. The water being supplied at high-pressure, all that is necessary is to affix a hose to the water-plug in the street, when a jet corresponding in height to the pressure is obtained, which can be immediately directed against the fire.

The ratio of the supply to the population varies in different towns. In Edinburgh, it is 34 gallons for each individual; in Glasgow, it is 50 gallons. This includes the water furnished to works of various kinds. The eight companies that supply London pour into the city and suburbs not much

less than 100 million gallons daily, which gives 206 gallons per house (including manufactories), or 26 gallons to each person.

There is great diversity of opinion among both practical and scientific men as to what is really a sufficient yet not extravagant amount of water to be provided for each individual per day, many advocating the principle of unlimited quantity and unrestrained waste, as tending to increase the prosperity of towns, and improve their sanitary condition. A continual stream of fresh water pouring down the drains is, in their opinion, an advantage, owing to the absorbing power of the water, which is supposed to oxidise the gases in the sewers, and thereby to act as a deodoriser and disinfectant. Others, again, of equally high professional standing, declare that every drop of water sent into the drains unnecessarily is nothing but sheer waste, and see no possible advantage in the continual contributions to the sewers, which invariably accompany the use of insufficient internal house apparatus. In short, the one party argue that 50 or 60 gallons per head is not a drop too much, while the others declare that whatever exceeds 12 or 18 gallons is unnecessary extravagance. Probably something between the two, or from 25 to 30 gallons per head, may be assumed as the proper amount. As adverse to the side of those who advocate an unlimited quantity, the fact may be noted, that in places where the supply is derived from pumping-engines, and where, consequently, every gallon pumped up, and then let run to waste, is represented by so much coal, and therefore by so much money thrown away, one never hears of indiscriminate waste being advocated.

In order to prevent waste, numerous contrivances have been adopted to a great extent in many English towns. One great source of waste arises from the ignorance of many people in supposing that the purity and sweetness of the drains is promoted by keeping the handle of the water-closet propped up so as to cause a constant flow of water through the pipe. Various contrivances have been devised, with a view to prevent this practice being followed, and also great improvements have been effected on the ball-cocks of cisterns, which, when out of repair, are very frequent sources of waste.

Artesian Wells—so called from Artois, a province in the north of France, where, it appears, the greatest attention has been paid to the discovery of subterranean springs—are distinguished from common wells by the circumstance of their waters rising above the surface, often to a considerable height, and with considerable violence. This fact, that water will rise spontaneously to and above the surface, in certain localities, when bores of various depths are made into the earth, seems to have been long known to mankind. An Alexandrian writer of the sixth century narrates, that 'when wells are sunk in the oasis of the desert, to a depth varying from 100 to 500 ells, water springs from the orifices, so as to form rivers, of which the farmers avail themselves to irrigate their fields.' In China, also, and in European countries, there are proofs of wells of this nature having been early formed.

Artesian wells are common on the continent, particularly in Austria and in France. That of Grenelle, near Paris, is one of the most famous and gigantic, the borings being carried through tertiary and chalk strata to a depth of 1798 feet, or one-third of an English mile. The bore is 20 inches in diameter at the orifice, but is contracted by stages, till at the bottom it is only 7 inches. The bore is lined with iron tubing; and the current, which discharges between 500 and 600 gallons per minute, rises to a height of 30 or 40 feet above the surface. The water has a constant temperature of 81·7°. The well, finished between 1833 and 1844, cost 303,000 francs. In Austria there are many artesian wells: one recently constructed at Pesth is some 3500 feet deep. Britain also has its share of deep wells of this kind. In many wells formed on the Artesian principle of penetrating through an impervious stratum to the water-bearing stratum of sand or chalk below, the water rises only partially up the shaft or boring, and not quite to the surface. This is the case with the wells of London that are sunk through the stratum known as the London clay. The level in these wells is annually sinking, shewing that this source of supply is already drawn upon to the full.

The geological and hydrostatic principles upon which the forcible discharge of Artesian fountains depends, are sufficiently obvious. The explanation will be more evident by a reference to the accompanying figure, which may be considered as a diagrammatic section of the London basin. There is here a number of porous beds, *b*, *b*, composing

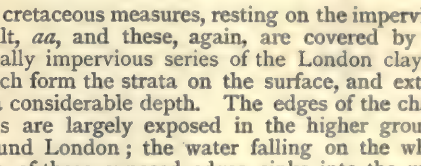


Fig. 4.—Section of the London Basin.

the cretaceous measures, resting on the impervious gault, *aa*, and these, again, are covered by the equally impervious series of the London clay, *cc*, which form the strata on the surface, and extend to a considerable depth. The edges of the chalk-beds are largely exposed in the higher grounds around London; the water falling on the whole area of these exposed edges, sinks into the more or less porous cretaceous beds, and would, in course of time, by continued accessions, fill up the basin, were it not prevented by the clay above. By driving a bore, *d*, through this superior bed, the inferior water-logged strata are reached, and the subterranean water rises to the surface, and flows continuously, by means of hydrostatic pressure.

Many such wells exist in London and its vicinity; those which form the ornamental fountains in Trafalgar Square descend into the upper chalk to a depth of 393 feet. Depending upon these principles, no Artesian well should be attempted without consulting the geologist or mining-engineer. A deflection of the strata, the occurrence of a dike, or some such phenomena, which the geologist alone can interpret, may render abortive years of labour.

Artesian wells are generally formed by *boring*, which is performed in much the same way as a

quarryman bores for blasting. The boring-head, or ram, consisting of a mass of iron, with steel chisels fixed in its under side, is made to rise and fall by a rod, or—according to the Chinese method, which is found preferable—by a rope, to which a certain torsion is given. Sometimes the débris is lifted by the ram itself; in other cases, a separate auger, or shell-pump, is from time to time applied. It is necessary, in soft strata, to line the bore with iron tubing.

Tube-wells.—The tube-well is an American contrivance, introduced into England in 1867, having for its object the obtaining of a small supply of water in a very short space of time by the application of a limited amount of manual power.

The apparatus comprises three parts—a tube or well, a rammer or monkey, and a pump. Fig. 5 shews the several parts, and fig. 6 the state when driven into the ground. The tube, AA, consists of an iron pipe about 1¼ inch diameter, made in pieces of convenient length, which can be screwed

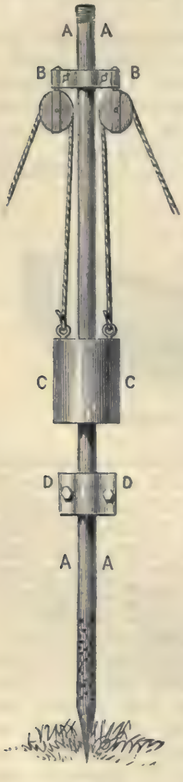


Fig. 5.

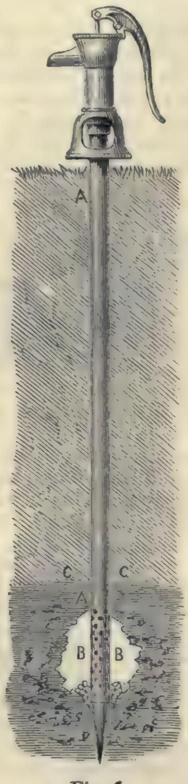


Fig. 6.

together end to end. The pipe terminates at the lower end with a solid-tempered steel point, and is perforated for about 16 inches from the end with small lateral apertures. The pipe is driven a short way into the ground, just sufficient to keep it upright without falling, and is temporarily kept in that position by hand. A strong iron clamp, DD, is fixed to the tube by clamping-screws at a short distance above the ground; and another clamp, BB, is similarly fixed higher up. Two pulleys are supported by the upper clamp. The rammer or monkey, CC, consists of a 56-lb. iron weight, which slides up and down the tube, encircling it like a ring or belt. The rammer, being raised by two men, is allowed to fall with its full weight on the lower clamp; thus giving a series of blows which drive the tube into the ground. Successive lengths of tube and successive shiftings of the clamps afford the means of enabling the perforated end of the tube to reach soil whence water can be obtained. When the symptoms appear of water having been reached, at CC, a small suction-pump, shewn at the top of fig. 6, is applied, and the water pumped. The inventor accompanied the American Federal army, and enabled the troops frequently to obtain water by the aid of these pumps.

Fountains—Jets-d'Eau.

Fountains or jets-d'eau are contrivances by which water is violently spouted or projected upwards in a continuous stream, so as to become at once ornamental, refreshing, and salubrious to the locality in which they are situated. The projecting force is acquired either from the hydraulic pressure of the water at the fountain-head, by the spring and elasticity of a confined volume of air, or by mechanical appliance; but generally by the first. The water is conveyed from the reservoir to the fountain in pipes, and if the orifice from which it issues be directed upwards, it will spout to a height approaching that of the reservoir.

Decorated fountains of this kind were much in request among the Greeks and Romans, not only in their streets and gardens, but also in the courts of their houses; and this fondness for fountains still exists in Italy and the East, where there are numerous elaborate and fanciful designs. The French are also celebrated for their fountains, those at the Tuileries, Versailles, and St Cloud being superb structures; and indeed, with the exception of our own, most of the large towns of Europe are adorned and refreshed by these contrivances. The most remarkable jet-d'eau in the world is said to be that at Cassel in Germany, where the waters rise from an orifice of twelve inches diameter to a perpendicular height of 200 feet. The source from which it is supplied is at the top of a mountain near by, being about 500 feet above the level of the town. The fountains of the Sydenham Palace are on a grand scale. The jets-d'eau, and cascades of the numerous basins, contain six times the amount of water thrown up by the Grands Eaux at Versailles.

DRAINS—SEWAGE.

Next to the necessity of an abundant supply of pure wholesome water, is that of getting rid of it when rendered foul and contaminated by use. This sewage problem is even more difficult than that of water supply; for while the difficulties of the latter have been tolerably well got over, the solution of the former is not yet completely settled. The most obvious method of discharge is by open gutters; but as these are offensive and unsightly, the great object, both in ancient and in modern times, has been to establish a system of underground channels or sewers.

Among ancient nations, the Romans carried underground sewerage to great perfection, in so far as removal of the excreta was concerned; and it is worth while, in these days of sanitary preachments, briefly to glance at their *cloacæ*—a term which includes not only the larger sewers which led to the Tiber, but the small drains or pipes of wood or clay leading into these. The whole city was thus intersected by subterranean passages. The most celebrated of these drains was the *Cloaca Maxima*, the construction of which is ascribed to Tarquinius Priscus, and which was formed to carry off the waters brought down from the adjacent hills into the Velabrum and valley of the Forum. The work is evidently of great antiquity. The arch of this cloaca is semicircular, and formed of three rings of voussoirs, as shewn in the annexed cut, being 14 feet in width. The blocks are hewn, and joined together without cement. The erection of such spacious sewers to take off the drainage-matters of houses which were mere huts in comparison, contrasts painfully with the indifference shewn until lately on these points by modern governments. In fact, until within the last fifty years there was hardly such a thing as systematic drainage of houses; and privy-pits and cess-pools prevailed everywhere. In the country, the former were generally placed in the garden attached to the house, and at some distance off, so that there was not much danger attached to them. In the towns, cess-pools existed among the houses, but they were very objectionable and dangerous, and constantly neglected. These cess-pools were large underground tanks built in brickwork, into which all the sewage from the house was discharged. In them the filth accumulated and putrefied until it was periodically removed by manual labour. They acted like immense brewing vessels, sending up deadly vapours, which had no escape, except back into the house among the inhabitants. The cess-pools also frequently leaked, and so, if any wells were near, poisoned the water. When Bramah invented the water-closet, and a larger supply of water had to be found for towns, the cess-pools began to overflow at such a rate, that a general revision of the whole system became necessary; and at the same time, medical men insisted upon the continuous and perfect removal of filth as the only reliable sanitary process of dealing with the matter.

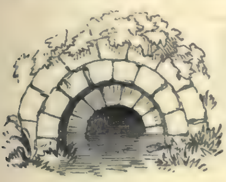


Fig. 7.

The subject may be divided as follows: 1. The Management of the Sewage of Cottages; 2. Dwelling-houses and Public Buildings in the Country; 3. Towns; and 4. The Utilisation of Sewage.

1. *Cottages.*—It is obvious that in the case of single detached cottages, expensive arrangements, such as those necessary for water-closets, could not be provided, and some simpler plan must be followed. The privy should be placed, whenever that can be managed, on the north or east side, and to the rear of the house. The whole sewage-matter should be received in a square galvanised iron pail underneath a seat, which pail can be removed from the outside, and into which a small quantity of house-ashes or dried earth should be placed, either daily, or as often as the closet is used. This will quite fix the ammonia. The iron pail should be removed at least once a week, and emptied into the garden, where there is one. No danger can possibly arise from this if strictly followed, and all the sewage-matter is turned to its proper purpose.

The application of this *earth-closet* system is not confined to single cottages. Chiefly through the zeal of the Rev. Henry Moule, vicar of Fordington, in Dorsetshire, it has been systematically worked out and introduced with success into numerous villages, hospitals, prisons, public schools, and barracks. It has been adopted on a large scale in India, where, indeed, its partial use had long been known. The deodorising effects of *dry* powdered earth, whether field-mould, brick-dust, or fire-ash, are quite remarkable; a slight covering effectually prevents all effluvia. It is found that 1½ pounds by weight, or 1½ pints by measure of dry earth, is sufficient for each time of using the closet. The closet may be in the form of a commode for use in a sick-room, in which case there is a metal pail under the seat removable by a front door; or it may be fixed in the place usually occupied by a privy or a water-closet. In this case, instead of the pail, there may be a cell lined with cement, and having the bottom paved with stone or asphalt. The earth is supplied by a box fixed behind the seat, and above the level of it; by means of a handle, a valve at the bottom of the earth-box is opened, and a definite quantity of earth falls into the pan or into the cell. In the fixed closet, the mixture of refuse and earth may go on accumulating for weeks with little appreciable odour. Dry earth may be procured in summer, and stored for winter use; or it may be dried in drawers or trays under a kitchen-range. No sand should be used with the earth and ashes; and no house-slops of miscellaneous kinds should be thrown into the pail or pit. The deposit has a value as manure of from 20s. to 30s. a ton.

Several modifications of the dry-closet system have been invented; and it has been introduced into manufactories. The charcoal or ashes of burned sea-weed are found to be a more powerful deodoriser than even dry earth; they have a much greater power of retaining the nitrogenous constituents of urine.

2. *Dwelling-houses and Public Buildings in the Country.*—It is not likely, however, that those who have once been accustomed to the common water-closet could ever be reconciled to the use of the dry-closet in the interior of dwelling-houses, and therefore the object is to render the use of the water-closet liable to as few objections as possible. In planning the position of water-closets for a house, the first thing to be thought of is, that they should be, if possible, on the north side of the house, and on exterior walls. If they are placed in the interior of the house, it is troublesome to get at the drainage if required, and the closets themselves are not so easily ventilated. Whatever form of closet is used, it must be provided with an efficient water-trap or cess-pool to prevent the reflux of foul air from the drain. The accompanying figure represents the mechanism of a water-closet, with a water-trap of the usual siphon form. It is desirable that the closet should be surrounded by brick walls, and, in fact, isolated

from all other parts of the house. A ventilating shaft, carried alongside a chimney flue, so as to

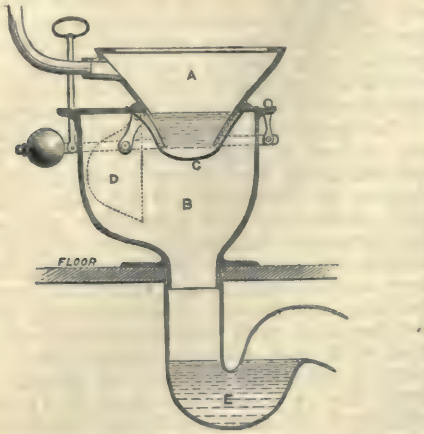


Fig. 8.

A, basin; B, metal trunk; C, copper pan; D, do. when open; E, cesspoool.

create a draught, and opening outside, is the most effectual way of ventilating a water-closet.

An essential point, and one but little attended to, is the ventilation of the drain-pipes into which the water-closets and sinks of a house empty themselves. It is evident that water-traps can exclude the foul air of the drains only when that air is under no extra pressure—a condition that is often wanting. In fact, whenever any part of the pipe or drain below the trap is filled with water, there must be a regurgitation of foul air into the house every time that water flows down the pipe. Any extraordinary rush of water into a drain, or even the difference of pressure between the warm interior of a house and the cold outside, will cause the resistance of the stench-traps to give way, and force poisonous gases into the house. A safety-valve should therefore be provided by carrying a ventilating-pipe from some part of the drain-pipe to a point as high at least as the roof. Another essential matter is the testing of the soil-pipes by hydraulic pressure, to detect holes in the lead.

In constructing the drains from houses or large public buildings, there should be an entirely separate system for the sewage or foul water, apart from that for rain and surface water. Stoneware pipes are the best material to be used for sewage-drains, because they are perfectly non-absorbent; but in many cases, glazed earthenware will answer very well. The smallest size of pipes of any description that should be used for removing sewage from a house is six inches in diameter. This size, then, may be gradually increased as is necessary, and one of nine inches will remove the sewage of 500 people. Any fall from an inch in five feet to an inch in 60 will work well enough, provided a body of water is allowed to pass through with a rush twice or three times a week. This is of more consequence than the gradual passage of a larger amount flowing daily in an equal, uniform stream. At every twenty yards there should be a pipe laid, from which the upper half can be removed, and any stoppage remedied without the necessity of breaking the pipes. Greasy water, such as is poured down from the kitchen and scullery of a house, is one of the constant causes of such stoppages. The fat, as it cools, congeals on the sides of the pipes, and forms a hard cake. The best method of preventing this is to form a small cess-pool, into which the kitchen water is poured first, and then to take an overflow through a siphon into the foul drain, so that the liquid only enters, while the fat can be removed by hand from the cess-pool.

The sewage-matter having been thus all thoroughly removed from the house, should be conveyed in the drain-pipe to some convenient spot where a sewage-filter should be built. The accompanying diagram represents one originally

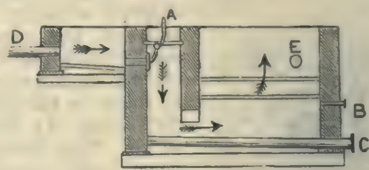


Fig. 9.

The whole sewage matter enters at D; flows in the direction of the arrows; the solid matter becomes arrested in the bottom chamber, while the liquid rises and passes off at E through filtering beds. By opening a tap at B the liquid in the tank or filter can be drawn off, and by opening that at C, the solid matter can be removed. The whole must be water-tight and air-tight. A is a valve for shutting the pipe during cleaning.

designed by Prince Albert. In this, the solid and liquid matters of the sewage are mechanically separated, and the former can be removed from time to time—say once in two months—while the latter should be applied to irrigation. To allow it to run into any stream, is not only dangerous and wrong, but illegal.

3 *and* 4. *The Drainage of Towns and Utilisation of Sewage.*—The arrangements of water-closets, &c. for the individual houses in towns are substantially the same as for isolated buildings in the country. The additional points to be here considered are the main drains and the outfall. Half a century ago, the only drainage existing in towns was for the rain-water and surface-water, all solid refuse and fecal matter being removed by the scavenger; but with the introduction of the water-closet, systems of drainage had to be designed to carry off both sewage and surface-water. The main drains were made large enough to allow a man to pass through them to keep them clean. Into these sewers, all the smaller house-drains were led, and the surface-water, through street gratings, passed into them as well. The ordinary water used for domestic purposes and the occasional rainfalls were relied upon to flush those large main sewers; but their great size made this an exceedingly difficult and uncertain process, and they, in fact, became only cess-pools elongated. A further step was then taken by sanitary engineers. The idea of men passing up the drains was set aside, and the smallest possible drains have been constructed, sometimes no larger than an 18-inch drain for a town of 10,000 inhabitants. These drains consist either of earthenware pipes or oval culverts built of brick or stone cemented. The rainfall is still relied on to a certain extent for flushing purposes, but a supplementary assistance is given at some points by flushing with water from the

ordinary supply of the town. As these smaller drains are not sufficient to carry off all the surface and rain water as well as the sewage, overflow weirs are provided at certain points where the excess must go over and pass away into some other channel. This is the system now most generally adopted; but it is attended with serious disadvantages to be afterwards noted.

The next point for consideration is the disposal of the filth at the main outfall. Hitherto, it has been the practice to carry the discharge of sewers into the nearest stream. The effect of this practice, taken in conjunction with an increasing population and the multiplication of manufactures, has been, that most of our streams and rivers, instead of being images of purity and beauty, have become offensive to the senses, and vehicles of poison to men and animals living near them. It is also very objectionable to empty sewage into the sea; for tide-locked drains are attended with many evils, and sewage mixed with salt water and exposed by the retreating tide is more offensive than ever. Various judicial decisions have shewn that this poisoning of the rivers is illegal; and legislation is daily tending more in the direction of making it obligatory on towns to use every possible means to purify their sewage of its noxious ingredients before allowing it to escape. How to remove from sewage the foul matters held in suspension in the water, is the difficult part of this great problem; and, inseparably conjoined with it is the further question, of how to utilise these matters. Dirt has been defined to be, 'Valuable matter in the wrong place.' When in its right place, it is riches, and its right place is the soil. As to the value of the ingredients of sewage as manure, there is little dispute; the real questions concern the method and cost of its application.

None of the attempts to purify sewage by chemical means—deodorising, as it is called—have succeeded. The only hopeful plan is the application, of the liquid portion at least, to irrigation.

Sewage irrigation, in a rough and imperfect manner, has long been practised with profit in the neighbourhood of Edinburgh. By this means, a tract of several hundred acres of meadow-land between the city and the sea is made to produce crops of grass worth from £20 to £40 an acre per annum. The effluent water, however, is still very foul. At Croydon, again, the sewage has been applied to irrigation with profit, and is also so purified as to prevent nuisance. In both these cases, however, the sewage flows upon the land by gravitation; and in the case of Croydon, a very considerable portion of the sewage which could not be utilised is poured into the metropolitan sewers, throwing on that body the difficulty of dealing with it. But in by far the greater number of cases it would have to be elevated by pumping, and it is here that the chief difficulty occurs. The difficulty is mainly occasioned by the uncertainty arising from the rain and surface water being mixed with the sewage; and hence the proposal to keep the sewage and rainfall separate, by a double system of drainage. The chief advocate, if not the originator, of this plan is Mr William Menzies, C.E. Deputy Surveyor of Windsor Forest and Parks, who laid down the principles in his work on *The Sanitary Management and Utilisation of Sewage.* The main objection to the plan is its apparent expensiveness at the outset, but this is a matter open to much consideration. Its advantages are many and obvious. The advocates of this double system of drainage say that the total separation of the two is the most sanitary method, because the street-gratings and rain-water pipes, which at present let down the rain-water into the sewage-drains, act, in fact, as so many ventilating shafts, and discharge the stench in the midst of the inhabitants; while, under a separate system, the sewage-pipe would be entirely sealed up, and only ventilated where it could be done with safety; that the rain-water as a flushing-power ought to be entirely discarded, as it fails in dry weather, just when it is most wanted; that in wet weather, and winter again, the great quantity of water sent down through the drains by the present system is agriculturally a serious injury; that when pumping has to be employed for lifting the liquid for irrigation, as it is in most cases, all is uncertainty, and that no machinery can be economical and efficient under such circumstances. With regard to the expense, it is further maintained that, as the rain-water and surface-water can be discharged at the nearest point, all the drains may be much lessened in size; and further, that the flushing-power of the water in the sewage-drains will be much more efficient, while the corresponding lessening of the expense in carrying out the process of utilisation will completely compensate any additional outlay that may be incurred in laying the drains in towns. If we take the case, which is a common one, of a population of 10,000 people living upon a square mile, the first-mentioned system, where rain and sewage water go together, would require pumping-machinery, in dry weather, of, say, five horse-power, to lift the liquid; and it would further be necessary, for wet weather, to have in reserve a lifting-power of 150 horses; while, on the separate system, where the sewage alone would have to be dealt with, the five horse-power engine would be regularly and constantly employed, and its work would be almost entirely confined to the daytime, whereas the other must be ready for every emergency.

The system of separating the sewage and rain-water has been carried out in several large asylums and public buildings, and the sanitary results have been thoroughly satisfactory. The principles of the separate system of drainage for towns were fully confirmed in the report by Colonel Ewart, C.B. R.E. appointed in 1866 by the Home Secretary to investigate this subject. The drainage of Eton has been since then completed from first to last on this principle, and the sewage utilised; and the system has been in operation in the town of Haddington since 1870.

In 1873, after five or six years' full consideration of every plan and scheme, the drains of Windsor Castle and all the crown buildings at Windsor were reconstructed on this system, under the charge of Mr Menzies and Captain Gun, R.E.

Presuming, then, that by this separation we can arrive at a fixed quantity of, say, 20 or 30 gallons of sewage per head of the population, the first step would be to pass the whole through a filter or strainer, so that all matter would be intercepted which would be likely to interfere with the pumping, or choke the smaller pipes used for irrigation. This is necessary, also, because in its

unfiltered state we cannot depend upon sewage going down and up again, and so passing over a valley. Great part of the solid matter can also be removed by this process, common house-ashes being the best mixing and deodorising material to facilitate the stuff being carried away.

A piece of land should then be sought out, with a slope, if possible, of one foot in 50, and the filtered liquid, which will be still rich in fertilising ingredients, conveyed either by pumping or gravitation to the highest point of that land. Iron pipes should not be used, if possible; but when the land to be irrigated is very flat, they must be. From the highest point of the land selected, the liquid must be conducted, by open channels or through common drain-pipes laid on to the surface, to all the different points where it is wished, and utilised for irrigation. The land adopted should be moderately porous, and then for every 100 people an acre may be allowed, but this varies much according to the nature of the soil. The land must be thoroughly drained and prepared. The best crops to be grown are Italian rye-grass, with alternately crops of vegetables, such as potatoes, cabbages, rhubarb, mangold. All these will luxuriate on the liquid, and we think we may say that the command of such liquid would be worth to any person from £5 to £10 an imperial acre, according to local circumstances.

When a sufficient area of land cannot be procured for full irrigation, purification may be secured, so far as we know, for a time at least, by what is called 'intermittent filtration.' This consists in letting the sewage liquid flow over the irrigation beds for six hours, and leaving them for the rest of the twenty-four to drain and imbibe air. The organic matter retained in the soil is by this means oxidised, and the absorbent power of the soil is thus revived and ready to receive a fresh dose. The mode of operation will be easily understood by the following quotation from the Fourth Report of the Rivers Pollution Commissioners (1872):

'Irrigation and intermittent filtration have been already named as methods capable of purifying the foul liquid discharges from town-drains to a satisfactory extent. With regard to the latter of these processes, which was initiated in our chemical laboratory, and there proved to be a most efficient mode of purification, we have now to report that it has been applied for eighteen months to the whole of the sewage of Merthyr-Tydvil. Twenty acres of a porous soil, drained from five to seven feet deep, have been here arranged by Mr J. Bailey Denton, C.E. in four series of beds, and over each series in succession the drainage-water from a town of 50,000 inhabitants, more than one-third of whom are connected with the sewers, is poured for six hours at a time. The beds are laid out with a sufficient slope to carry the sewage (gradually sinking as it flows) from one side to the other within the allotted time, being thus irrigated from a nearly horizontal channel along the upper edge of each; and each being left to drain and become aërated during eighteen hours of every day, they bring into successful operation the process of intermittent filtration on a very extensive scale. These beds are, moreover, cultivated, and large crops of cabbages have been grown on them. These works have been carried out under an order of the Court of Chancery, directing the Merthyr Board of Health to abate the nuisance which the sewage of their town was creating in the river, and appointing Mr Bailey Denton to direct the necessary works. They were designed by Mr Denton expressly for the purpose of realising on a large scale the results of that process of intermittent filtration which had been devised and investigated in the laboratory of this Commission; and we have twice inspected them, and on both occasions have found the effluent water purified to an extent much beyond that required by the standards of purity suggested by us as those below which refuse liquids should not be permitted to enter rivers.

'The experience of these filter-beds at Merthyr has made plain, what the experiments in our laboratory had previously established, that towns can cleanse their sewage upon a much smaller area, or rather within a much less quantity of land, than any experience hitherto of sewage irrigation had led them to expect. Two processes of sewage purification by the use of land are thus now open to them, both of which have been sufficiently tried upon a working scale. They will, no doubt, endeavour to obtain a large extent, as heretofore, wherever land conveniently situated and of suitable contour is to be had cheap, and they will then irrigate with such a quantity of sewage per acre as will enable them to realise the largest possible returns from the cultivation of irrigated crops. Where, however, the only land available is costly, or its configuration is unfavourable for irrigation, they will prepare a smaller area by deep and thorough drainage of the subsoil, and accurate formation of the surface, for the reception of much larger quantities of sewage për acre, and seek, by carefully carrying out the process of intermittent filtration, to insure the perfect oxidation and defecation of their now offensive drainage-waters. It is, of course, only where irrigation is conducted in the less intensive manner, upon the larger area with the smaller quantity of sewage per acre, that any hope can be entertained of an adequate return for the money invested, although even a mere filter, wherever the liquid cleansed by it is in itself of a fertilising nature, is by no means necessarily without some return, since at Merthyr-Tydvil Mr Bailey Denton has shewn that healthy and luxuriant crops can be grown upon it.'

How long the soil will continue to act in this manner is at present unknown. Vegetation, it is known, will thoroughly purify foul liquid, but the inert earth may not have unlimited powers in that capacity.

On the whole, although we have made considerable progress in this science, much labour and thought must be bestowed upon it before safe conclusions can be drawn applicable to all cases.

BATHS—WASH-HOUSES.

Referring the reader to the article on the PRESERVATION OF HEALTH for the sanitary value of personal ablution, we shall here treat of baths as a social arrangement, and of the various mechanical appliances requisite for the establishment of a system.

BATHS OF THE ANCIENTS.

The use of the bath, natural or artificial, has existed, in all probability, from the beginning of the world, since it is founded in the most natural wants of man. The Greeks knew the use of warm baths in the time of Homer. At a later period, they had public baths attached to the *gymnasia*, and the richer families also had baths in their private houses.

The Romans were late in introducing artificial baths. But in the reign of Augustus, they began to give to their warm baths that air of grandeur and magnificence yet to be observed in the ruins which remain. Bathing among the Romans was not a mere dip. It embraced a variety of operations, including gymnastic exercises, performed in a succession of apartments, and with water of all temperatures, accompanied also with the use of unguents and perfumes. The baths were frequented indiscriminately by individuals of all ranks; the noblest and richest persons there finding themselves mingled with the poorest plebeians.

It was not only the Roman metropolis which contained public and private baths; they existed in all the towns of Italy, and in the palaces of nobles and freedmen; they were found also in all the Roman provinces. The greater number of these magnificent edifices, which, during the most illustrious period of the empire, had constituted the pride and delight of Rome, were destroyed by the vandalism of the barbarian hordes. Those which were not pulled down, were otherwise employed, or, being no longer repaired, gradually fell into ruin. In the middle ages, baths on a more moderate scale were introduced as the ancient structures disappeared. The vapour and public baths were, for a long period, as much frequented in Europe as they are at the present day in the Levant.

MODERN BATHS AND WASH-HOUSES.

Although the increasing use of linen has much diminished the hygienic necessity of the bath, and has occasioned the ruin and neglect of the establishments of the middle ages, yet public attention has not ceased to be directed to the advantages of such establishments. The more expensive class of houses are now generally fitted up with accommodation for hot and cold bathing; portable baths on the sponge, shower, or plunge principle, are common in the dwellings of the middle classes; and deficient as we yet are, the last few years have witnessed the erection of a number of private and public establishments, at which the masses may enjoy a bath for the merest trifle of their weekly earnings. Bathing should be deemed a necessity, not a luxury. The great majority of our artisans and factory-workers are engaged in labour of a kind by no means cleanly; and without daily ablution of some sort or other, disease and injured constitutions are certain, sooner or later, to be engendered; to say nothing of the refinement of feeling associated with cleanliness.

We shall speak presently in detail of public baths; but where steam-engines are employed in connection with cotton-factories or other works, there is usually a certain quantity of waste steam or waste hot water at disposal, which could, at an insignificant cost, be directed into baths for the use of the workmen of the establishment. The improved health and cheerfulness of the parties benefited will more than compensate the necessary outlay.

Another modern improvement, the public wash-house, calls for mention. The very limited house accommodation of the poorer classes in towns affords little or no convenience for washing. Independent of this, in point of economy, a public wash-house is preferable to any number of isolated efforts. By co-operation, superior accommodation, better apparatus, and a cheaper and more satisfactory result, can be obtained; and thus the public wash-house, where self-paying and self-supported, may be classed among the co-operative arrangements which characterise the age. When we consider the amount of fuel required for a kitchen-fire on a washing-day, the time wasted by imperfect arrangements, the inconvenience experienced where the housewife has to wash, dry, and iron her clothes in the one sole room where she has to cook the family meals, and where that family has perhaps to eat, sleep, dress and undress, and perform all the minor offices of life, we can then appreciate the boon which a public wash-house is calculated to confer.

So far as concerns wash-houses in England, the credit of a reformer is due to Mrs Catherine Wilkinson of Liverpool, who, in a year of cholera, bravely offered the use of her small house, and the value of her personal superintendence, to her poorer neighbours, to facilitate the washing of their clothes at a time when cleanliness was more than usually important. The success attending the exertions of a single individual led to the formation of a benevolent society to carry out the object on a large scale.

In 1844, a public meeting was held at the Mansion House, to encourage the formation of baths and wash-houses in London; hence resulted an 'Association for Promoting Cleanliness amongst the Poor.' A reform had already been commenced by a 'Committee for the Houseless Poor,' who rented an old roomy building in Glasshouse Yard, surrounded by the poor and dense population of the London Docks district. A bath-house and a wash-house were fitted up; baths, cisterns, boilers, cold and hot water, towels, soap, soda, were provided; and the poor were invited to come in, and wash and bathe without expense to themselves. The Association, afterwards founded at the city meeting, sought two objects—to induce a wish for cleanliness among the poor; and to render public baths and wash-houses *self-paying*, as a guarantee for their permanency. The Association built a model establishment in Goulston Square, Whitechapel; and in the meantime, another society had succeeded in establishing baths and wash-houses in George Street, Hampstead Road, favoured by a liberal arrangement on the part of the New River Company in the supply of water: this establishment was opened in August 1846.

But we have now to speak of rate-supported baths and wash-houses. In 1846, parliament passed an act to enable borough-councils and parish vestries to establish public baths and wash-houses, supported by borough and parish rates, if the householders should sanction such a proceeding. The chief of these clauses are: that the requisite funds may be raised on the security of the

poor-rates, at 4 per cent.—to be repaid by thirty yearly instalments; and that the minimum charges, for the benefit of the poor, should not exceed one penny for a cold bath, twopence for a warm bath, and one penny per hour for laundry conveniences. The parish of St Martin's-in-the-Fields was the first to take advantage of the new act; and before the close of 1852, six parishes had erected public baths and wash-houses, and in each establishment attempts were made to introduce improvements in the practical details. At the beginning of 1856, the list had nearly doubled. The Marylebone Public Baths and Wash-houses had from the first paid their working expenses, and contributed towards defraying the cost of construction; but in some of the others the bathers and washers have been barely numerous enough to pay the working expenses.

In the extra-metropolitan counties of England and Wales (Scotland and Ireland were not included in the provisions), Liverpool was the first town to adopt the Baths and Wash-houses Act; four or five establishments are maintained in different parts of the town. By the Return prepared in 1865, it was found that, though much good had been wrought, it scarcely realised the anticipations which had been entertained; for, in nearly twenty years since the passing of the act, only 25 towns out of 192 had adopted it. Some of the very large towns, such as Liverpool and Manchester, have special powers for these and allied purposes conferred by acts applying to those towns alone. The most costly single establishment is at Birmingham, the outlay having been £46,000.

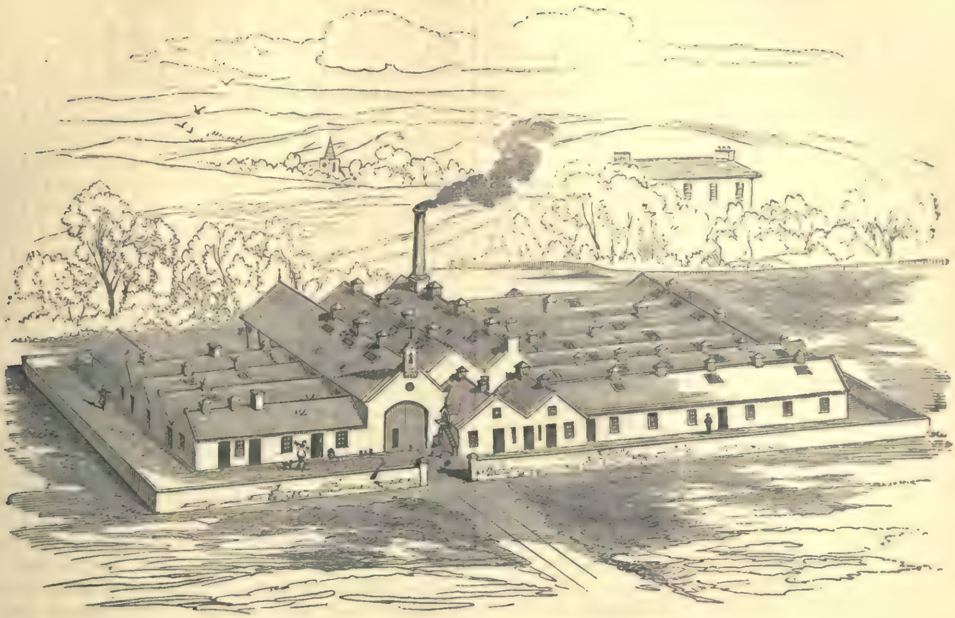
The public and private baths of the metropolis, all included, are about fifty in number.

The Local Government Act (1858) affords facilities apart from those above noticed, for the establishment of baths and wash-houses. Bathing and washing are regarded as being among the numerous sanitary matters of which the Act empowers the authorities of a town to take cognizance. So far as power is concerned, this Local Improvement Act (which has been largely adopted), coupled with the former acts, would suffice for the supply of most of our large towns with public baths and wash-houses; but there is reason to believe that the citizens have been rather remiss in taxing themselves for this purpose.

In nearly all the London baths and wash-houses, which may also be taken as types of those in the country, the characteristic features are as follows: The baths for males and females are on opposite sides of the building, separated in some instances by the washing-room, and in others by the plunging-baths. The separate baths, in large, well-lighted and well-ventilated rooms, are shut in by walls generally of slate, and the baths themselves, supplied with fifty or sixty gallons of water for each bather, are either of zinc or enamelled iron. There are two, three, or four classes of baths, charged differently according to the amount of accommodation afforded. In some instances there are tepid as well as cold swimming or plunging baths; while two or three of them afford facilities for shower and vapour baths.

Much more interesting, however, are the wash-houses, as examples of a great improvement. The washing-room is provided with numerous small compartments, doorless and roofless, each for one person. Each compartment contains a boiler and a washing-tub, with taps for hot water, cold water, waste water, and steam: all unlimited in quantity, wilful waste, of course, being guarded against. An American washing-board assists the operations; and a rack-work stand protects the feet. The steam from all the compartments is carried upwards to one great ventilating shaft. The 'wringing' of the wet washed linen is effected by putting the articles into a sort of perforated cylinder, which is then rotated with great velocity; the centrifugal force drives out the water through the perforations and interstices, leaving the linen, though damp, much drier than it can be made by the familiar laundry process. The clothes are then taken to the drying-room, where they are hung on frames or 'horses' in small chambers heated with hot air to about 200° or 210°. It is found that 10,000 or 12,000 articles of washed clothing can now be dried with £1 worth of fuel. The ironing is done in a large ironing-room, well provided with irons, ironing-blankets and boards, and heating arrangements. The charge is from 1d. to 2½d. per hour, according to the class and the accommodation.

It has been found, by actual results at one of the establishments, that 37,000 garments—an aggregate of all the usual kinds—belonging to 1370 washers, were washed, dried, and ironed in 3000 hours; that is, each woman, on an average, working about two and a quarter hours, began and finished the washing and ironing of her family stock of twenty-seven articles. When the model establishment was first founded, the fuel for heating 1000 warm baths cost £3, 15s.; but by successive improvements, this cost was reduced to £1, 4s. There are, it is found, in the metropolis about three times as many bathers as washers; both classes together, they pay about 4d. each on an average; and nearly the same average has been observed in the provinces. In Scotland and Ireland, the public baths are gradually increasing in number; but the wash-houses have not been much encouraged.



Bird's-eye View of Covered Homestead.

AGRICULTURE.

MAN is the sole inhabitant of the earth that selects, for the purposes of cultivation, other plants than what the soil naturally brings forth. The spontaneous growth of nature affording but a limited quantity of food for man, he supplements the supply by capturing the wild animals, which often feed upon what is unsuited for his sustenance. But even in the most favourable circumstances, a given area of territory cannot maintain many of the human family, so long as they depend upon the natural vegetation or on the chase. It is only after those plants which yield man an abundant supply of food are made the objects of cultivation, that population augments, and civilisation begins.

In temperate latitudes, the *cereals*, or corn-bearing grasses, have always been the chief plants from which civilised man has drawn his subsistence. But excepting in a very few spots, none of these are found growing in a wild state. To give full possession of the ground to the cereals, man must wage a perpetual warfare with the indigenous plants which are ever ready to spring up and occupy the ground.

It was a profound observation of Adam Smith, that 'the most important operations of agriculture seem intended not so much to increase, though they do that too, as to direct the active fertility of nature towards the production of the plants most profitable to man. A field overgrown with briers and brambles may frequently produce as great a quantity of vegetables as the best cultivated vineyard or cornfield. Planting and tillage regulate, more than they animate, the active fertility of nature.' To yield such results, the plants of nature must possess certain advantages over those which man cultivates. To comprehend the nature of these differences in the requirements of plants, and to enable us more readily to understand the philosophy of the practices of agriculture, the sciences connected with that art will each shortly occupy our attention.

CHEMISTRY OF AGRICULTURE.

The elementary substances occurring in plants, whether wild or cultivated, are oxygen, hydrogen, nitrogen, carbon, sulphur, phosphorus, chlorine, iodine, bromine, fluorine, potassium, sodium, calcium, magnesium, aluminum, silicium, iron, manganese. These eighteen elements are rarely all combined in one plant. It is supposed that certain of them can be substituted for one another. Thus, sodium and potassium, being somewhat similar in their nature, are sometimes found in varying proportions in the same kinds of plants that have grown on different soils. But the presence of many of them is indispensable, and there can be no substitution in their case. In this position stand the first-named six elements.

The principal mass of all plants is made up of oxygen, hydrogen, nitrogen, and carbon. When

a plant is burned, these elements are driven off in the form of gases, and the other elements that had entered into its composition remain as *ash.* It has been customary to call the four elements that disappear by combustion, the *organic elements*, and those that remain in the ash, the *inorganic elements* of plants. But the distinction is without ground. All the elementary substances that are constantly found in a plant, must be considered as necessary parts of its structure or organism, and, in this position, are all equally organic.

With the exception of oxygen, none of the elements found in plants are taken up in the elementary state, but only in a state of chemical combination with other elements. Thus carbon by itself is not food for a plant; it must first be united with oxygen, forming carbonic acid, and in this state it is readily imbibed. Similarly, plants do not take up simple nitrogen, but nitrogen combined with hydrogen, in the shape of ammonia. The substances thus taken up as food by the plant, become united by means of its vital action into definite chemical compounds, called *organic* compounds, because they exist or are formed only in organised beings. Chemists, however, have now very generally adopted the views of Liebig, that the compounds which constitute the food of plants are all inorganic. The inorganic substances, carbonic acid, water, and ammonia, with the alkaline and earthy substances found in the ashes of plants, are now regarded as their only nourishment.

The organic compounds of plants may be divided into two great classes—nitrogenous and non-nitrogenous; that is, those which contain nitrogen, and those which are devoid of it.

We know little or nothing of the chemical processes that take place in the interior of plants during their growth. The manner, indeed, in which the particular compounds are determined is still involved in complete mystery. Liebig, however, with his usual sagacity, has pointed out that phosphorus and sulphur are always associated with nitrogenous matter, and that the alkalies and earthy bases direct the formation of substances devoid of nitrogen.

The growth of all plants takes place by the formation of cells, and the nitrogenous structure of cells precedes the non-nitrogenous. In all probability, it is for this reason that phosphates act so favourably on the growth of some plants when applied as manure at an early stage. By phosphates assisting in the formation of the cells of the rootlets of plants, rapid growth is induced. The plants are put in possession of the soil more quickly by obtaining a ready supply of phosphates, and thus obtain the other matters which are fitted for their growth.

The nitrogenous substances found in plants and in animals are usually of the same composition, though they differ in their form. All kinds of wood contain quantities of nitrogenous or albuminous matter, which is identical with the muscle of animals, but most frequently it is not in a fit condition to be assimilated by the larger class of animals. An oak-tree, with its acorns, is composed of nearly the same elements as a ripened plant of wheat.

It has been truly said by Dr Anderson, that as the analysis of plants has become more perfect, so has the difficulty of explaining the necessity of a rotation of crops, on mere chemical grounds, become greater.

The analyses of the ashes of plants by Professor Way, contained in the volumes of the Royal Agricultural Society, put this in a strong light. The subjoined table exhibits the quantity of the alkaline and earthy matters found in an acre's produce each of wheat, turnip, flax, mangel-wurzel, beans, and maize. The wheat-crop is reckoned at 28 bushels of grain and 18 hundredweight of straw; the turnip at 20 tons of bulbs and 4 tons of tops; the flax at 20 bushels seed and 2 tons of straw; the mangel at 20 tons of bulbs and 4 tons tops; the bean at 35 bushels grain and 1 ton of straw; the maize at 48 bushels grain and 1½ ton of straw.

	Wheat.	Turnip.	Flax.	Mangel.	Bean.	Maize.
Silica......pounds	84	13·2	22	13	3·17	36
Phosphoric acid "	20	45·	25	21	16·	31
Sulphuric acid.. "	4	50	8	22	3	6
Lime.......... "	8	90	51	21	25	13
Magnesia...... "	6	14	12	22	6	12
Peroxide of iron "	0	..	9	..	0·69	3
Potash........ "	22	140	59	133	64·	56
Soda.......... "	2	33	6	70	3	..
Chlor. of sodium "	..	57	20	160	13	3
	146	442	212	462	144	160

The marked feature in this table is the large amount of alkalies and alkaline earths that the fallow crops, turnips and mangel-wurzel, require in comparison with wheat. Silica enters largely into the composition of wheat-straw, and only sparingly into other crops. The turnip has more phosphates in a crop of twenty tons than any of the others in the table; still, the beneficial influence which phosphates often have when applied as manure to this crop, must be attributed to other causes than to the mere extra quantity in their composition.

Soils can be fertile only if they contain a supply of alkalies and earthy bases sufficient for the full development of plants. But soils become exhausted for many kinds of plants, even when they contain abundance of these elements. Some plants are more dependent than others on a supply of carbonic acid and ammonia in the soil. Such differences in the requirements of plants lead us to treat of

THE PHYSIOLOGY OF AGRICULTURE.

Carbonic acid, water, and ammonia, which constitute the chief food of all plants, exist in the atmosphere and in the soil. Plants have the power of obtaining them from both these sources—taking them from the atmosphere by means of their leaves, and from the soil by their roots. Carbonic acid and ammonia become fixed in the leaves of plants by virtue of chemical affinities directed by the vital agencies. Two essential conditions of atmospheric absorption are—first, that the soil supply the requisite quantity of moisture; second, abundance of the substances found in the ashes of plants. These conditions being favourable, the amount of carbonic and ammonia that a plant will draw from the atmosphere will, other things being equal, depend upon the surface of leaves which it exposes to the air during the growing season. An oak-tree, which has an immense surface of leaves exposed to the atmosphere, has greater facilities of abstracting carbonic acid and ammonia than the wheat or

turnip, which must first receive a liberal supply of these substances from the soil, in order to form a surface capable of taking food from the aërial medium.

Plants like wheat and turnips are said, naturally enough, to be great exhausters of the soil, because they cannot be raised unless they are fed or manured by materials yielding an abundant supply of carbonic acid and ammonia. It is now generally admitted that a liberal supply of substances yielding nitrogen is essential for raising a maximum produce of grain and root crops. At the same time, it must be borne in mind that nitrogenous manures have a beneficial influence on all our cultivated crops, but some crops are more dependent on a supply than others, and some can digest or assimilate more in a given time.

The first great physiological distinction which may be drawn with respect to the capabilities of plants for drawing a supply of food from the atmosphere is, that *annuals* are much more dependent on a supply of carbonic acid and ammonia in the soil than *perennials*. Indeed, comparatively speaking, annuals exhaust, but perennials ameliorate the land.

Perennials have not everything to do in one season, for every year strengthens their hold upon the soil, and increases the surface of leaves which they expose to the air. Perennial vegetation, therefore, often exhibits considerable luxuriance when the soil is deficient in matters yielding carbonic acid and ammonia. On the other hand, the larger class of annuals are never found growing luxuriantly on soils deficient in substances yielding carbonic acid and ammonia. In fact, annuals must be so far regarded as a sort of parasites. The thriftless annual casts away its roots and stems, which, as they decay, are liable to be washed out of the soil by the rains. A perennial plant, however, may be said to be manured, and well manured too, by its roots and branches, which are kept in a vital state. The habits of growth in perennials are thus of a very economical character.

It is annual plants that principally supply man with food in the temperate latitudes. Their grand deficiency in having no perennial roots and branches must be made up by manuring. Thus all our fallow crops, such as turnips, mangel, beans, and potatoes, are freely treated by substances yielding carbonic acid and ammonia. These crops being all annuals, are particularly dependent on a supply of such substances.

On the other hand, when our fields become exhausted by the growth of cereals, we restore their fertility by abandoning their cultivation for a time, and allowing them to accumulate vegetable matter through the growth of perennials, such as grasses or clovers. Annuals succeeding perennials, perennials succeeding annuals, has been the primitive rotation—when a rotation was necessary—in all countries and in all ages. It was Liebig who first demonstrated that the effect of pasturing land was to accumulate ammonia from the atmosphere.

The more nearly that an annual approaches in its habits to a perennial, the less dependent it is upon a supply of carbonic acid and ammonia in the soil. So long as an annual plant puts forth fresh leaves, it is capable of drawing upon the food contained in the atmosphere, and therefore less dependent on a supply furnished to its roots. Thus a pea, which puts forth fresh leaves and blossoms, and even ripens fruit at the same time, can draw more largely from the atmosphere than the wheat-plant, which puts forth no fresh leaves after it flowers, when the most of the leaves lose their vitality. The wheat-plant, being in a great measure devoid of foliaceous surface, must be liberally supplied by manure, and hence it has the character of being an exhausting crop.

Viewing the physiological aspects of the question, the principle may be stated so as to embrace annual and perennial vegetation in the following terms: *Plants are less dependent on a supply of carbonic acid and ammonia in the soil when their vegetative powers coexist, as they do in grasses and clovers, with their flowering and seed-forming processes.*

As was pointed out by Liebig, the atmosphere contains a supply of carbonic acid and ammonia sufficient for all the plants that grow upon the surface of the earth, whether wild or cultivated. This proposition is rendered evident when we reflect that an acre of land under a forest assimilates as much carbon, oxygen, hydrogen, and nitrogen during the growing season, as an acre under any of our crops, such as turnips or clover. It is well to bear in mind, therefore, that the necessity of manuring our fields with substances yielding carbonic acid and ammonia, does not arise so much from a deficiency of those substances in the natural source of supply, the atmosphere, as from an inherent deficiency in the plants cultivated for drawing largely upon this source.

Perennials not only possess greater facilities of abstracting food from the atmosphere, but they have greater facilities of abstracting it from the soil. By forgetting this very obvious principle, great confusion has arisen among agricultural writers respecting the action of some manures. For example, much ingenious speculation has been indulged in to account for the well-known fact, that phosphates have, as a general rule, a more beneficial action on the turnip-crop than on any other. This, however, admits of a simple and consistent explanation, when we reflect that the size of the seed of the turnip is immensely less in proportion to the space which the plant ultimately occupies, than is the case with any other plant.

The seeds of clover and grasses are small, but as they are thickly sown over the ground, the individual plants do not require to run far in search of phosphates; and they have also more time to search for a supply. With the turnip, it is different; it is sown at a season of the year when vegetation is stimulated by a high temperature. The small seed of the turnip has no phosphates within itself to produce a large growth of leaves and rootlets; and thus, unless it have a liberal supply added as manure, it cannot grow with vigour or rapidity. For this reason, phosphates must often be added to the soil to produce a crop of turnips, when these substances are by no means wanting, and not even deficient in quantity for growing other crops, which must absolutely obtain a supply as large, but whose facilities for obtaining it are much greater.

The practical application of these principles, however, will be further illustrated when we come to treat of manuring particular crops. The next theoretical division of our subject is one which has an intimate bearing on the physiology of

plants, and also an important influence on the practices of agriculture.

THE METEOROLOGY OF AGRICULTURE.

The proportions of oxygen and nitrogen in the atmosphere are very uniform at all places on the earth, at all heights above its surface, and at all seasons of the year. Dry air contains about 77 parts of nitrogen, 23 of oxygen, and one 2000th part of carbonic acid by weight. The atmosphere also contains minute quantities of ammoniacal vapour, which furnishes a supply of nitrogen to plants. Besides these, the vapour of water is always a component of the atmosphere, though it varies more in quantity than any of the others. The higher the temperature of the air, the more moisture can it hold in an elastic state. (See METEOROLOGY.)

There are good grounds for believing that the amount of ammonia in the air is directly as the quantity of moisture it contains. The supply is larger in hot and moist weather than in cold and dry. This supposition is so far supported by the fact, that it takes more manure to grow a plant in spring than in summer.

In illustration of this principle, we have only to bear in mind that market-gardeners who force plants early in the season, require to dress their land with the richest manures. Phosphoric manures have no effect on turnips which are sown early in the season, though they are well known to have a very beneficial influence when applied to turnips sown in June. The vivifying influences of a high temperature have no doubt much to do in giving plants greater vigour to abstract ammonia from the soil; but when all the facts are fully considered, they indicate that the leaves of plants have not only greater powers of absorbing ammonia directly from the atmosphere in warm than in cold weather, but that there is more for them to absorb. There is a numerous array of agricultural facts which appear to admit of no other explanation.

The theoretical dictum which has been put forward by English writers, 'phosphates for turnips, and ammonia for corn,' has led to much misconception regarding the facts involved. If it be necessary to draw distinctions on this head with respect to the requirements of annual plants—always bearing in mind the qualifications we have made —it is pretty near the truth to say, '*ammonia for spring, and phosphates for summer.*'

Keeping in view the principles that have been so far illustrated, we shall, in approaching the more practical subjects, now touch upon the

PHYSICAL CONDITION OF SOILS.

This is one of the most important elements that determine the natural distribution of plants over the surface of the earth. To maintain plants in a healthy growing state, they must obtain a certain supply of moisture from the soil. Plants require different amounts of moisture from this source, as some evaporate a larger quantity of water from their leaves than others. The capacity which soils have of retaining the rains which fall, or of absorbing moisture from the atmosphere, has thus a great influence on their fertility.

In a state of nature, we find plants that require little moisture for their healthy growth take possession of barren sands; while those that require a larger amount, fix upon soils which are more absorbent or retentive of moisture.

The agriculturist must often endeavour, however, to make all varieties of soil fitted for growing the particular crops that are most in demand. As his art advances, and his resources become more numerous, the mechanical condition of soils is more under his command, and he strives to give the different varieties such treatment as will fit them for growing all kinds of plants, irrespective of their physical characters.

Tillage, or other means of disintegrating and pulverising the soil, has the effect of rendering it more absorbent of moisture. It thus so far compensates for a larger fall of rain. Tillage, however, is more particularly useful as a means of putting annual plants in possession of the soil, and of causing the organic matter which it contains to decay. Many perennial plants are not benefited by tillage, and most are independent of it. Thus, all our ameliorating crops, such as grasses and clovers, receive no cultivation, and produce as much vegetable matter as those that do.

This fact is rendered still more apparent by viewing what takes place in the forest, where the roots of the trees obtain a greater supply of moisture from the shade which the leaves afford. The shade of the forest is the natural substitute for the absorption of moisture that takes place in a well-tilled field.

Agriculturists classify the particular physical conditions of soils under the following general heads: sandy, gravelly, clayey, chalky, alluvial, and loamy.

Sandy soils, containing a large percentage of silicious matter, are often unfruitful, owing to the shallow-rooted plants being readily scorched during warm weather. Many of our sand-downs in the vicinity of the sea are of this character, and hence they are more profitable when allowed to remain covered by the grasses which are natural to them. These soils cannot absorb much moisture from the air, nor retain what falls as rain. Sandy soils are most productive in moist seasons or in moist climates. Sir Humphry Davy found that the coarsest and most barren soils, when dried at 212°, absorbed least moisture in a given time.

Gravelly soils derive their name from resting on gravel. They are usually sandy in their character, and contain pebbles and boulders; but being liable to be scorched by droughts, their produce is variable.

Sandy loams contain a larger proportion of vegetable matter than the above, and thus being more absorbent of moisture, are better fitted for maintaining plants in healthy conditions. Sandy loams are benefited more than any other class by tillage, which increases their absorbent powers. These qualities fit them especially for turnip-husbandry.

Loamy soils are of great variety, for the term *loam* is one of the most indefinite in agricultural language. Loam may be generally described as a mixture of sand, clay, and vegetable mould, moderately cohesive, less tenacious than clay, and more so than sand. These qualities render them suited for all kinds of crops, which are raised with greater certainty than upon any others.

Clayey soils, if they contain little vegetable matter, are the most difficult class to cultivate.

Unless they are managed so as to allow the frost of winter to assist in their pulverisation, it is often a most difficult matter to effect this by all the implements at the command of the farmer. Drainage, however, has done a great deal towards rendering this class more easily cultivated; and at present, they are made to produce excellent green crops in ordinary years. Clover and artificial grasses produce heavy crops of hay on clay soils, but the pasture is generally inferior, as the treading of stock seems to be adverse to the healthy growth of grasses on these soils.

Chalky soils have a large proportion of calcareous matter in their composition. The valleys of the chalk districts in England, however, usually abound in clay, and the soil is particularly tenacious. The chalk loams are well suited for the growth of all kinds of crops, more especially of wheat, barley, clover, and turnips. These are the only soils upon which sainfoin and lucern thrive.

Alluvial soils are composed of the finest particles of earth which have been washed by floods from the upper part of the courses of rivers. They have generally a rich level surface, and being deep, yield excellent crops of wheat, oats, barley, beans, potatoes, and clover. To manage these lands well, the farmer must undergo a thorough training, so as to enable him to cultivate them properly, with the least expenditure of labour. A celebrated soil from Ormiston, in East Lothian, which contained more than half its weight of finely divided matter, absorbed, in Sir Humphry Davy's experiments, six times more water than the soil from Bagshot Heath.

Varieties of soils, however, are as numerous as the rocks from which they have been formed. The adaptation of the different varieties of soil for the growth of particular crops, will be best illustrated when we come to consider the culture of the particular crops.

THE CHEMICAL CONDITION OF SOILS.

In nature, we find the earth covered by a vegetation that thrives upon the same spots for ages. But it is well known that if some of our cultivated crops are frequently repeated on the same soils, they become a prey to different kinds of diseases. In nature, those plants which are fitted to the chemical condition of the soil, take possession of it; but man endeavours to make certain plants grow upon every variety of soil.

It is well known that sainfoin and lucern will not thrive upon land unless it contains a large quantity of calcareous matter. Now, the analysis of the ashes of these plants does not indicate that either of them requires more lime for building up its vegetable structure, than some others that thrive upon soils containing but a small quantity of calcareous matter. Turnips, it is well known, are subject to finger-and-toe, a disease for which a liberal application of lime to the soil will act as a preventive. That the lime in this case, however, does not act by merely affording lime as a constituent to the crop, is evident from the fact, that it does not cure finger-and-toe when applied, like other manures, at the time the crop is sown. It must be applied for a year or two previous, that it may have time to produce a certain chemical effect upon the land. The particular action in this case, we have been led to believe, consists in the lime directing or controlling the particular decomposition that all vegetable matter is undergoing in the soil. The particular products that an unlimed soil often yields interfere with the healthy action of the absorbing powers of the roots of plants, which are thereby prevented from taking up a due supply of the earthy matters. The deficiency of these matters induces a corrupt state of the vegetable juices, which thus become the *nidus* for particular kinds of insects. It has always appeared to us that the insects are not the cause of the disease of finger-and-toe or anbury, as Professor Buckman supposes, but a consequence of diseased conditions.

Vegetable physiologists who suppose that plants absorb their food mechanically along with water, are evidently at fault. The process is apparently a chemical one, similar to that which takes place when leaves absorb carbonic acid and ammonia from the atmosphere. But, more than this, we have long been led to the conclusion, before being aware of Gazzeri's experiments, that roots virtually exercise, by their contact with solid matter, an incontestable action in imparting solubility to it.

In order that the roots of plants may exercise on the substances constituting their food an absorbent action, which is equivalent to a power of selection, they must be placed in a medium capable of maintaining their healthy functions.

This peculiar chemical condition of soils, which is a quality over and above the mere presence of the constituents of plants, is a highly important one. Finger-and-toe in turnips, clover-sickness, the dying out of certain grasses in particular soils, and many phenomena in the vegetable world, arrange themselves for elucidation under this head.

The particular quality of soils, also, which practical men distinguish by the terms 'sharp' and 'deaf,' arises from their chemical condition. It ought to be borne in mind that the repetition of a particular crop on any soil does not necessarily unfit the soil for producing it in a healthy state, if the chemical conditions are favourable. In many soils deficient in calcareous matter, the quantity of crude vegetable matter which turnips leave by their decaying roots, impairs the healthy functions of their roots when too frequently repeated. Lime cures this quality of the land, by correcting or neutralising the decomposing matters left in the soil. One of the most interesting facts elicited by Mr Lawes in his experiments at Rothamsted is, that he has raised turnips on the same land with superphosphate of lime for eight or ten years in succession. The American farmers also sow clover every other year, but do not complain of clover-sickness. Clover-sickness and finger-and-toe, however, sometimes arise from an actual deficiency in the soil of the substances found in the ashes of the plants.

CLIMATE OF GREAT BRITAIN.

The effects of climate on crops and systems of farming will be best treated when considering the culture of particular crops, and the practical economy of rotations. Under the present head, we shall confine ourselves to some general remarks on temperature, rains, and evaporation.

However useful the *means* of monthly temperature may be for some purposes, they are of little

use for illustrating the effects of climate on crops. The mean may be made up by a wide range of temperature, or the reverse. Thus, a mean of 60° may be made up of a maximum of 75° and minimum of 45°, or a maximum of 65° and a minimum of 55°. Such atmospheric conditions, however, would be attended with different effects on the soil and plants. Did our space permit, we would shew that the mean maxima and mean minima temperatures put us in possession of data to estimate the effects and intensity of many climatological influences. The following are the mean maxima and mean minima temperatures in the different months at a few stations which, being calculated for the same thirteen years—namely, 1857 to 1869—are comparable *inter se*.

TEMPERATURE.

	Jan.		Feb.		Mar.		April.		May.		June.		July.		Aug.		Sept.		Oct.		Nov.		Dec.	
	Max.	Min.	Max.	Min	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max	Min.	Max.	Min.
	°	°	°	°	°	°	°	°	°	°	°	°	°	°	°	°	°	°	°	°	°	°	°	°
Helston	49·8	40·4	51·0	41·0	52·2	40·8	58·1	44·7	63·1	48·3	68·4	52·6	71·8	55·0	70·5	55·1	66·8	53·2	60·9	49·1	53·8	43·0	51·6	41·8
Greenwich	43·3	33·3	46·9	34·7	49·6	35·2	57·7	40·5	65·0	44·2	71·7	50·3	74·9	52·7	73·2	52·8	68·3	50·0	59·3	44·5	48·6	36·6	45·5	35·9
Clifton	43·7	34·7	46·2	35·8	48·5	36·0	57·1	40·7	63·0	44·8	68·3	50·9	71·3	53·5	69·6	53·4	65·3	50·1	57·6	45·2	48·4	37·4	46·1	37·1
Lampeter (Wales)	45·0	32·8	46·9	35·9	49·1	35·1	58·5	38·1	63·6	43·0	68·7	47·5	71·2	49·6	70·1	48·5	65·8	47·2	57·6	44·2	49·4	36·0	47·1	35·3
York	41·2	32·0	43·4	34·4	45·8	35·0	53·6	39·6	59·5	44·3	65·9	50·5	68·0	52·4	66·7	52·9	62·2	48·8	55·0	43·8	47·0	36·4	42·8	35·2
Coldstream	41·5	32·6	43·8	33·1	46·2	34·0	52·7	37·7	58·6	43·2	64·1	49·9	66·1	50·9	65·6	50·2	62·0	48·7	54·1	41·5	46·1	34·9	43·7	34·1
Dundee	41·5	32·9	44·5	34·0	46·4	34·3	52·6	37·8	57·6	42·2	63·7	48·1	66·4	50·4	65·6	50·4	61·8	47·0	53·7	41·8	46·2	36·0	43·4	35·2
Callton Mor (Crinan)	43·3	33·8	44·3	34·9	45·5	35·1	52·1	39·1	57·6	43·6	62·8	49·0	64·4	50·9	63·6	50·3	60·9	47·7	54·2	42·3	47·1	36·8	45·3	36·7
Elgin	41·3	32·9	43·3	33·7	44·6	34·1	51·8	38·4	57·4	42·7	63·7	48·5	65·5	50·2	64·7	49·8	60·5	47·0	53·7	40·3	45·4	35·9	43·9	35·1
Sandwick (Orkney)	42·1	35·4	42·5	35·3	42·8	34·3	47·3	38·1	51·9	42·2	56·7	47·8	58·2	50·0	58·5	50·1	56·1	48·2	50·5	43·3	45·6	38·6	44·5	37·7
Dublin	46·1	35·1	48·0	35·8	48·4	36·4	55·6	39·6	60·6	43·4	66·1	48·3	69·0	50·4	67·5	50·1	63·8	47·2	56·8	44·8	49·6	37·0	47·6	37·0

The highest summer day temperature occurs in the district round London. Wheat is cultivated with great success in Morayshire (Elgin); but the northern limit of cultivation of this cereal extends only a little to the north of this; hence the mean day temperatures of this place possess great value, as indicating the approximate limit of the profitable cultivation of wheat. At Sandwick, wheat and barley do not ripen properly, the region of the cultivation of these cereals being now passed. The temperature of 40°, or rather 39°·2, the maximum density of fresh water, is an important temperature with reference to vegetation—experience having shewn that little vegetation takes place when the temperature of the nights falls to 39°·2. In this respect, the table is of great value.

The quantity of rain which falls in different districts is another important point. The table below gives the amount of rain in inches at the following stations, with the number of years for which the averages have been calculated.

RAIN.

Stations, and No. of Years.	Jan.	Feb.	Mar.	April.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Year.
	in.	in.	in.	in.	in.	in.	in.	in.	in.	in.	in.	in.	in.
Guernsey......28..	4·1	2·4	2·7	2·2	2·3	2·0	2·2	2·0	3·2	4·8	4·0	3·8	35·7
Helston........23..	4·0	2·6	2·8	2·5	2·4	2·2	2·4	2·6	3·3	4·4	3·8	3·8	36·8
Exeter.........47..	3·2	2·5	2·4	2·4	2·2	2·4	2·2	2·2	2·7	3·7	3·8	3·5	33·2
Brighton.......21..	2·4	1·4	1·7	1·4	2·0	1·8	1·9	2·0	2·7	3·8	2·4	2·5	26·0
Chiswick......40..	1·7	1·4	1·4	1·5	2·0	2·0	2·4	2·4	2·5	2·7	2·2	1·4	23·6
Oxford.........43..	1·9	1·5	1·5	1·7	1·9	2·4	2·5	2·4	2·7	2·6	2·1	1·7	24·9
Clifton.........19..	3·1	1·9	2·1	2·0	2·4	2·6	2·6	3·3	3·2	3·5	2·2	2·6	31·5
Lampeter......17..	4·6	3·0	3·2	2·5	2·4	2·6	2·9	3·2	4·7	5·3	3·7	4·6	42·7
Cardington....26..	1·8	1·2	1·4	1·6	1·8	2·0	2·1	2·2	2·1	2·4	1·6	1·5	21·7
Norwich........19..	1·9	1·7	1·6	1·4	1·9	1·8	2·2	2·1	2·6	2·4	2·4	2·3	24·3
Grantham .....17..	2·0	1·2	1·7	1·4	1·7	1·9	2·3	2·6	2·3	2·6	1·9	1·7	23·3
Derby..........28..	2·0	1·6	1·9	1·9	1·9	2·6	2·5	2·9	2·6	2·8	1·8	2·1	26·6
Manchester....47..	2·5	2·4	2·4	2·0	2·4	2·9	3·6	3·6	3·2	3·8	3·5	3·2	35·5
Stonyhurst.....25..	3·9	3·9	2·9	2·5	2·4	3·7	4·0	4·5	4·4	5·4	3·9	4·6	46·1
York............19..	1·7	1·3	1·5	1·5	1·8	2·2	2·3	2·9	2·6	2·5	1·8	2·1	24·2
Silloth.........18..	3·3	2·3	2·1	2·2	2·4	2·4	2·4	3·3	3·4	3·5	2·9	3·1	33·3
Langholm......16..	6·3	4·5	3·8	2·6	3·1	3·6	3·1	5·0	4·8	5·9	4·4	5·7	52·8

Stations, and No. of Years.	Jan.	Feb.	Mar.	April.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Year.
	in.	in.	in.	in.	in.	in.	in.	in.	in.	in.	in.	in.	in.
Dumfries......22..	4·2	2·8	2·2	2·0	2·1	2·4	2·5	3·6	2·8	3·8	2·8	3·8	35·0
Largs...........30..	5·2	4·1	3·3	2·8	2·4	3·2	3·7	4·4	3·5	4·7	4·3	4·8	46·4
Greenock......36..	7·1	6·0	4·6	3·3	3·2	3·9	4·2	4·9	4·8	6·0	5·7	7·1	60·8
Bothwell ....28..	3·0	2·4	1·9	1·6	1·8	2·4	2·6	2·7	2·5	2·9	2·4	2·6	28·8
Callton Mor....16..	5·2	4·2	3·5	2·9	3·0	3·2	3·5	4·8	4·9	5·5	4·3	6·3	51·3
Kelso............18..	2·2	1·4	1·7	1·4	1·8	2·2	2·4	2·2	2·2	2·7	2·1	2·3	24·6
North Berwick 36..	2·0	1·4	1·4	1·3	1·6	2·5	2·6	2·5	2·6	2·4	2·1	1·7	24·1
Edinburgh.....50..	1·8	1·6	1·6	1·4	1·7	2·4	2·7	2·7	2·3	2·5	2·1	1·9	24·7
Stirling.........20..	5·0	3·6	2·5	2·0	2·0	2·7	3·1	3·5	3·0	3·8	2·8	4·2	38·2
Dundee.........17..	2·7	2·1	1·8	1·9	2·0	2·3	2·5	2·5	3·0	3·2	2·3	2·6	28·9
Aberdeen......34..	2·6	1·9	1·9	1·8	1·6	2·0	2·3	2·7	2·4	3·1	2·8	2·8	27·9
Inverness......31..	2·2	1·8	1·4	1·3	1·4	2·0	2·6	2·6	2·3	2·5	2·2	2·2	24·5
Sandwick.......31..	3·9	3·2	2·8	2·0	1·7	2·0	2·4	3·0	3·1	4·7	4·1	4·3	37·2
Dublin..........31..	2·3	1·8	1·8	2·1	2·2	2·2	2·5	2·7	2·3	2·9	2·5	2·2	27·5
Waterford.....11..	5·3	2·5	3·1	2·4	2·6	2·7	2·8	3·7	3·7	4·0	3·6	4·4	40·8
Cork............15..	4·2	2·5	2·9	2·4	2·3	2·0	2·0	2·7	3·2	3·6	3·4	4·4	35·6

More rain falls on the west coast than on the east; but it is worthy of observation that the excess is principally confined to winter and autumn. In the eastern and central counties of England and Scotland, where the annual rainfall is small, most rain falls during the warm months; but the evaporation being great, the climate is then dry. At western stations, the autumnal rains set in earlier than in the east. In the north of Great Britain, the driest period of the year is the month of May; but in the south and south-east, this occurs at least two months earlier.

From these tables, the distinguishing peculiarities of climate in different parts of the British Islands are apparent. The warmer nights and cooler days of Cornwall give as high a *mean* as the cooler nights and warmer days in Middlesex. Even when the fall of rain is the same at two places, the effects of this different composition are very marked upon crops, inasmuch as the range of temperature determines to a considerable extent the force of evaporation.

The drying or evaporating power of the atmosphere is also an important matter to be attended to. The range of the thermometer is less on mountains than in valleys, and, consequently, corn is always more difficult to harvest on high grounds, owing to the diminished evaporation. (See METEOROLOGY.)

CULTIVATION.

One of the principal objects of cultivation is to uproot and destroy all plants but those that the farmer desires to rear. No implement has been found to effect this so well, and at the same time so economically, as the plough, which Mr Mechi has facetiously termed 'an undertaker and grave-digger.' It ought to be borne in mind that it is of quite as much importance to have the grasses in a field of pasture completely buried, as to have the land thoroughly pulverised. The pulverising of the land, though it has the effect of rendering it more absorbent of moisture, is chiefly useful for the purpose of allowing plants readily to take possession of it. In this matter, the same principles in a measure apply as in manuring. The smaller the seeds of vegetables, the quicker their growth; and the larger the full-grown plants, so much the more careful and perfect must the preparation of the ground be. Thus, it is well known that the turnip requires a better tilth than other crops.

The plough no doubt at first sight appears a very simple implement; nevertheless, upon no one has there been so much mechanical skill expended, in rendering it adapted to different varieties of soil. In ploughing, an important principle must be steadily kept in view—that clay or tenacious soils should never be ploughed when either too wet or too dry. In ploughing the first time for fallow or green crops, it is of importance to begin immediately after harvest, or as soon after wheat-sowing as possible, in order that strong tenacious soils may have the full benefit of the frost. On wet stiff soils, frost acts as a most powerful agent in pulverising the earth: it expands the moisture, which, requiring more space, puts the particles of earth out of their place, and renders the soil loose and friable. On such soils there is no rule of husbandry more essential than to open them as early as possible before the winter frosts set in. If left till spring, clay soils may be too wet for ploughing; or if the season be dry, the earth, when turned up, will be in hard clods, very unfit for vegetation. Therefore, on farms having a proportion of clay and of light soils, it is necessary that the strong wet land should be ploughed first, provided the weather will allow.

Ploughs.*

From the time when animal power was first applied to the cultivation of the soil, an implement of various forms has been used for the purposes of a plough. In primitive times, it usually consisted of a piece of bent wood, attached to which was a broad share, either hardened in the fire, or faced with iron, a single handle, and no mould-board, or rest; and in those regions where the burning sun destroys the surface-matting of turf, such a simple instrument may still be used. But the requirements of modern agriculture have called forth an implement of greater power and perfection of form. A hundred years have not elapsed since the only plough in use in Scotland was rude, cumbrous, unwieldy, and usually drawn by eight oxen. When horses were attached to it, a lighter form was required; and after rural improvements began to spread, James Small, a Scotch ploughwright, had the merit of changing its form, and adapting it to the wants of the time. He duly proportioned the several parts, and fitted the coulter and share to cut, and the mould-board to raise and turn, a rectangular-shaped furrow, at a much less expenditure of force, and with greater precision than had ever been done before. For many years, this was almost the only plough used in Scotland. Wilkie of Uddingston, having formed all the parts of the implement of iron, made some alterations upon the set of the coulter

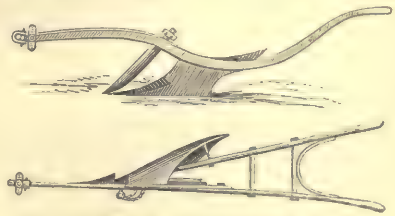


Fig. 1.—Swing-plough.

and share, and also on the form of the mould-board, so that on thin clay soils narrower furrows might be produced, with a greater shoulder or apex than the rather plain flat work which characterised Small's plough. With various slight alterations by different makers, until thorough-draining changed the texture of the soil, there was little improvement effected upon this implement. But since then, various alterations have been made both in England and Scotland. Ponton in West Lothian, and Sellars, Huntly, are the most recent improvers of the swing-plough. The first-named maker constructs his with long convex mould-boards, and irons set to cut high; Sellars, again, has the long mould, but his are plain cutting ploughs. Mr Finlayson, Bridge of Allan, has recently attached a couple of wheels to the common plough, by which all the regularity and equality of the English wheel-ploughs are attained; the wheels can be detached, and the implement again used as a swing-plough. In England, wheels had been in use from a remote period; and there the spirit of improvement took advantage of these to construct an implement capable of making excellent work, with the assistance of little skill in the workman. In Scotland, most of the improvements implied the existence of great skill in the ploughman; and the result has been that in such hands the Scotch swing-plough is able to produce any description of work, while that of the English wheel-plough is always the same. Ransomes of Ipswich has the merit of originating several improvements on the wheel-plough, and his latest form is represented, fig. 2. During the last thirty years, not a few makers have been keenly contesting for the merit of constructing the implement that produces the finest work at the least cost of power. Mr Howard has been tolerably successful: his plough somewhat resembles the above; and Mr Busby of Bedale, with the assistance of Mr Oathwaite, contrived very beautiful mould-boards, which were held first

* For the following remarks upon ploughs, grubbers, and harrows, we are indebted to Mr Melvin, Bonnington, Ratho, who has devoted much attention to the principles upon which they are constructed; the portion on agriculture generally, is by the late Mr R. Russell of Pilmuir, Fife; and the remaining section on spade husbandry and the culture of waste lands, was prepared by Mr J. Clarke of Long Sutton, Lincolnshire.

at the Exhibition in 1851. For several soils we prefer his plough to others; although Mr Ransomes, with his last improvement, has again taken the lead. None of these very beautiful implements please the Scotch farmer in ploughing lea, as they turn the furrow rather flat over; but they unite in a high degree those contrivances which go far to make up for the guiding-hand of man. They have long finely shaped mould-boards, rather short broad shares, straight coulters, and with the two wheels on level land, can almost move unattended. It is difficult to lay off land into ridges

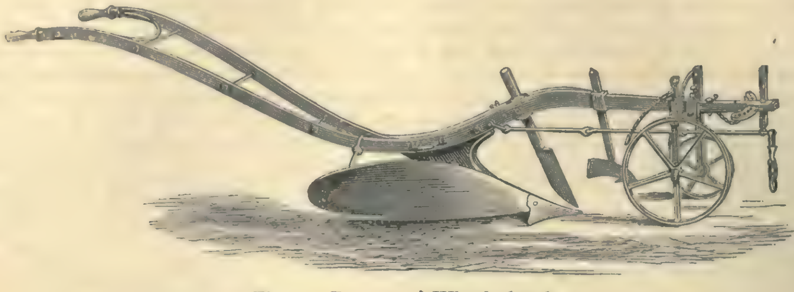


Fig. 2.—Ransomes' Wheel-plough.

with them, and drilling cannot be done, neither do they answer for the mode of ploughing which is called *gathering* in Scotland, as the space which is left when the last furrows are taken out is very broad; and they do not make the neat close finish that the swing-plough, when well handled, does. It may almost be said that, with the wheel-plough, it is the plough that does the work; with the swing, it is the man. It is not necessary here to enter upon any full examination of the principles upon which the various ploughs are constructed. In Scotland, they may be divided into two classes—the first follow Small's model, and are what are called plain cutting implements; the other, Wilkie's, which are capable of both plain and high-shouldered work. In England, all the ploughs we have seen cut plain—that is, raise and lay the furrow at an angle of about 45°. After the land became drained, considerable difficulty was felt with the concave moulds, from their not throwing the soil cleanly off; and to amend this, a longer and more convex form was adopted. These are now coming into general use.

Double-furrow Ploughs.—These ploughs were first exhibited at the Highland Society's Show in Edinburgh in 1869, as patented by the Messrs Pirie. Since then, their adoption by practical farmers has been remarkably rapid, and they are now largely manufactured by all the leading firms of agricultural implement-makers, and are said to be in practical use on the larger half of the tillage-farms in Great Britain. They are certainly highly useful for obtaining seed-furrows, after turnips or potatoes. Some contend that, from the use of wheels and the abolition of side-plates, the friction is so diminished, that a pair of horses can turn over two furrows as easily as one with an ordinary plough. Three horses, however, are generally used in ploughing stubble, and even lea, but it is even then severe work. Without denying their utility under certain circumstances, the advocates for deep tillage maintain it to be more profitable to employ three horses in taking only one furrow, even on the majority of soils, and entirely to restrict the use of double-furrow ploughs to seed-furrows.

Trench Ploughs are either worked with three or four horses, and are constructed on the same principle as the plain cutting common ploughs, but with all the parts larger and stronger. The ploughs constructed by the Marquis of Tweeddale for this purpose unite to a certain extent the properties of the subsoil and trench plough. Although they have been before the public for a good many years, and have succeeded well at Yester, as yet their adoption has not become general.

The Subsoil Plough is now less heard of than it once was. Although the theoretical principle on which the operation of subsoiling is founded is undoubtedly correct, and although the implement, as improved, effects the breaking up of the subsoil thoroughly, yet the effects visible from its use are frequently not so great as to induce those who most hopefully commenced with it, to continue further operations. Read's, as improved by Slight, Edinburgh, is the steadiest and best implement. Some subsoil ploughs of very light construction can be drawn by two horses; but in ordinary subsoils, the stronger implement cannot be effectually wrought without four horses, besides the pair in the common plough which throws off the surface-furrow.

Steam-ploughing and Cultivation has within the last ten years become a great established fact, and, though still in its infancy, its progress, if not rapid, is at least steady. At this moment (1873), there are nine private individuals in East Lothian who possess steam-ploughs, besides the Scottish Steam-plough Co., who have implements on hire not only in that county, but throughout Scotland. The depth and perfection of cultivation by steam-power, leave all work performed by horses far behind. The great drawback against their purchase by individuals is the large prime cost of engines and implements. The double-engine system of Fowler & Co. costs from £1500 to £1600. The fixed single engine of James and F. Howard & Co. can be obtained for about £700 or £800. Each apparatus has its admirers, and the choice depends on the greater or lesser quantity of ground requiring to be annually operated on. A system on a new principle has lately been introduced by the Messrs Fiskin, where the engine is stationary, and may be some distance from the field to be cultivated. The power is communicated from the engine to the plough or cultivator by

means of a long manilla rope, running at a high speed. It has obviously some important advantages over all other systems, as the engine works continuously, the movement or stoppage of the implement being wholly regulated by the individual having charge of it. If the farmer has sufficient ground to employ a steam-apparatus for a moderate length of time annually, the purchase of one will not be regretted, otherwise, the best plan is to hire for the deep and thorough autumn cultivation of stubble-ground.

Ploughing.

As steam-ploughs turn all the furrows one way, land is generally ploughed contrary to the way last done, or across the furrows. The old method of ploughing in ridges, *gathering* and *cleaving*, is wholly exploded: draining enables this to be done, and the reaping-machine requires it.

Casting is now by far the most common method of ploughing land by horses. The ploughman proceeds to set up poles eighteen feet from the side of the field. Along this line he throws out two furrows right and left, returns them again, and ploughs round these until thirty-six feet have been gone over; forming thus two ridges. He then measures a space of fifty-four feet from the last-drawn furrow, or seventy-two feet from his first-drawn line; again sets up his poles, ploughing other thirty-six feet there, and leaving a space of thirty-six feet between the two first-ploughed pairs. This space, forming two ridges, he now proceeds to wind out, turning always to the left, instead of to the right as before. In this way, any breadth of land may be wrought. It must be borne in mind, that the longer the length of ridge, and the fewer turnings, the more work can be performed; and that angular-shaped fields are expensive to cultivate.

The first and most essential property of every plough is, that it shall throw the furrow cleanly off the mould-board; when earth adheres to any part of it, the friction thereby causes loss of power, and the furrow is imperfectly turned; weeds are not covered in, and the old surface not turned down. The next is, that it shall leave the furrow in that position that exposes the greatest amount of soil to the action of the air; and also, that the furrow so turned over, while preserving that shape, shall be so rent internally by the action of the irons in cutting and raising it, that the air and frost may be enabled most easily to penetrate its substance. If, then, we are right in this position, either very long or very short mould-boards are objectionable: the last from breaking up too much the shape; and the other from polishing off too smoothly the exposed surface. The action of the plough on the soil is not so effectual as that of the spade, from the spitfuls being all separately cut. But the amount of surface which a well-turned furrow presents to the air is much greater than what any digging can throw up; and hence the advantage of having the furrows continually broken by frequent rents, and these openings not plastered up by a long mould-board, as is done in some of the more recent forms of plough, which compress and smooth the furrow after it has been fairly put in its place.

In the construction of ploughs, strength must never be sacrificed to lightness; a stone or two more weight is often of use in heavy soils; and the beam, head, and stilts must be thoroughly stiff and unyielding, when under the pressure of the horses and man, in the soil. A well-constructed plough should never be touched by the ploughman, either with the screw-driver or hammer. The share and coulter are the only parts he has control over.

A form of plough, known as the *turn-wrest*, is much used in Kent, and is highly thought of by the farmers there, as admirably adapted for clearing the land from grass, &c. as well as for loosening the soil. It is capable of being used for a variety of purposes. A view of it as improved by Mr Smart of Rainham, and manufactured by Ransomes and Sims of Ipswich, is given in fig. 3.

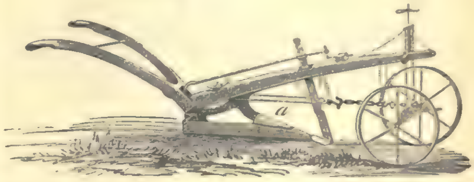


Fig. 3.—Smart's Turn-wrest Plough.

The turn-wrest plough lays the furrows all in one direction, from one side of the field to the other; this being effected by the wrest *a*, which acts as the mould-board of the ordinary plough, and by a very simple mechanism can be changed from one side of the plough to the other—'so that either becomes alternately the mould-board as the furrow requires to be turned.'

Grubbers

are now much more in use than formerly, the soil being more open and easily penetrated by their teeth. It is often far more advantageous simply to loosen up the soil than turn it over. Especially since green crops have been extensively grown on clays, this implement is almost essential, as thereby the disadvantages of a spring-furrow are dispensed with. The upper portion of the soil, loosened and pulverised by the winter's frost, not being turned down, still allows the drill-plough to form an open, friable ridgelet for the seed. In the cleaning of land, this implement is also most advantageous; and we know of nothing better for this purpose than an improved Scoular or Kirkwood grubber, with two wheels about two and a half feet in diameter, and the teeth proportionally long. They not only work the land most effectually, but never clog, as those with wheels of smaller diameter do; and when tested along with the one-wheeled Tennant's or Scoular's, are infinitely superior. On sloping land, when crossing the slope, a one-wheeled instrument works very imperfectly. Much of the bad odour into which grubbing has fallen in some places, has arisen from the use of imperfect implements, or from the want of properly trimming them; but it must always be borne in mind that surface-weeds are not removed by grubbing. Where these abound, and are troublesome, there is nothing like the plough for destroying them. The quantity of land which a two-horse implement will go over in a day, is generally four times the quantity which

the same team could plough. In Scotland, the grubbers chiefly in use are Tennant's and Scoular's one-wheeled ones, and Scoular's and Kirkwood's three-wheeled implements. In England, there are, under the name of Cultivator, Coleman's and Johnston's, Bentall's Broadshare, Ducie's Drag, &c. all of which are more complicated and heavy, with more cast-iron in their construction than those in Scotland; but they work well when sufficient horse-power is applied to them.

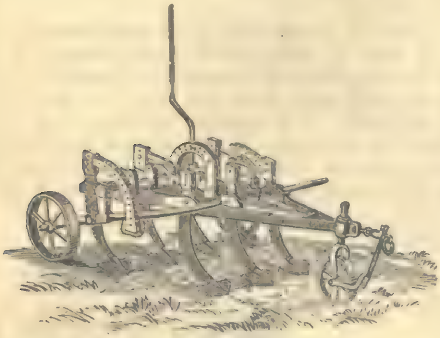


Fig. 4.—Coleman's Cultivator.

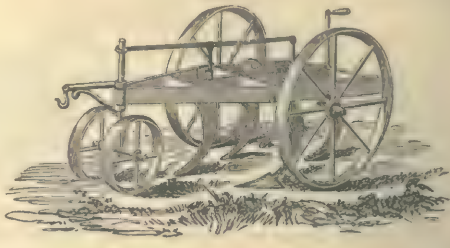


Fig. 5.—Ducie Drag.

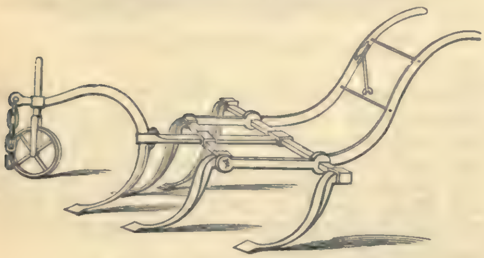


Fig. 6.—Tennant's Grubber.

Fig. 7.—Scoular's Grubber.

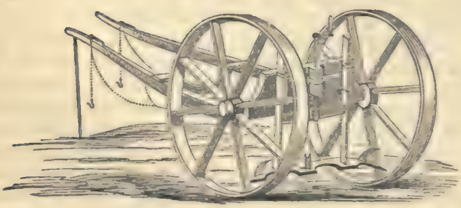


Fig. 8.—Johnston's Skim Cultivator.

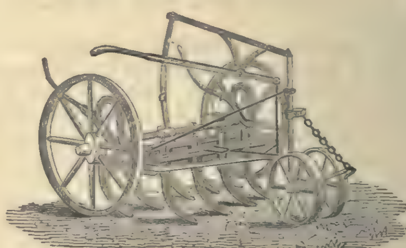


Fig. 9.—Biddell's Scarifier.

We believe that more attention to the action of this implement in the soil would result in the construction of still greater improvements than have hitherto been effected. It has never been determined what form of tooth is best—some advocating a diamond-shaped point; others, a broad chisel; and others, a duck-foot shape. We prefer, after many trials, a broad chisel-point, four inches at least, which, with the bend upwards, works the soil very effectually, but requires considerable force.

Harrows.

The early form of harrow was that of a board of wood with wooden pins fixed in it. Iron then took the place of wood for these teeth; and at length it was found that a framework of wood, consisting of *slots* and *bulls*—to use the language of the joiner—into which iron tines were driven, made a more effective implement. These harrows were generally made of a square form, and one was allotted to each horse. By making these of a rhomboidal shape, and coupling two together, and attaching a long tree to them, as in fig. 10, the irregular action on the soil of the former kinds was avoided, and each tooth operated on a separate portion of soil and at an equal distance from the one next it, as shewn in the dotted lines. These harrows have long been made entirely of iron, and are very effective on several sorts of land;

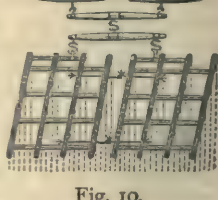


Fig. 10.

but not so on all, as there is too great rigidity about them, and they do not adapt themselves to any slight irregularity of surface, so that a more pliant implement was required. This, to a certain extent, was found in the Bedford harrow, originally constructed in three divisions, and containing seventy-two teeth, being thirty-two more than in the common harrow. The first formation of these Bedford harrows has been changed by introducing joints into the separate connections, and thus a far more pliant, though necessarily weaker implement has been produced, as shewn in fig. 11.

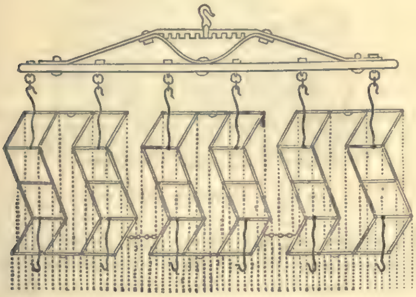


Fig. 11.—Howard's Harrow.

These harrows work admirably in the same line as the furrow; but in crossing they are apt to pull back the closing furrows of the ridges; and on newly ploughed or stiff lea ground they are objectionable on this account. They are heavier to draw than the common kind, and do not shake out the quicken roots or couch-grass very freely when the land is being cleaned: on this account, it is preferable always to have both sorts on the farm. The Bedford harrow costs about £1 more than the rhomboidal. Other forms have been introduced. All harrows are now made to cover a space of nine feet, and are drawn by one pair of horses. In ten hours, about sixteen imperial acres can be gone once over. As it is often necessary to go from four to seven times over the same ground before the surface can be made sufficiently fine, it would seem advisable to have an implement covering a narrower space, but more effective, so as to save several of these repeated journeys.

There is a useful article called a *drill-harrow*, for cleaning and lowering down bean and potato drills. This implement consists of two parts, each of which fits over the top of the drill, and, being concave on the under surface, acts on the top and sides. It is drawn by one horse, and is very effective.

Other sorts of harrows there are for the purpose of cleaning the intervals between the rows of green crop; but these are now less used, the horse-hoe being made to do much of the work to which they were applied.

The Norwegian harrow is an implement which is much used in some localities; and as it can be wrought in showery weather, when it is impossible to have rollers going, it has advantages which commend its use. It acts more in the way of cutting than compressing, and is also preferred on this account.

The *roller* and *clod-crusher* are implements that cannot be dispensed with on any farm. The smooth iron roller is too well known to require any description; and Crosskill's clod-crusher is acknowledged to be a very efficient implement for strong clay lands; but the Cambridge roller has superseded it for general purposes, and is now considered the best in use. Like Crosskill's, it consists of a series of rings strung on an axle, and while they fit closely, each has an independent motion; but while Crosskill's leaves the ground rough, it is made smooth by the Cambridge, though raised into small half-circles, with a narrow indentation betwixt each.

Carts.—Two kinds of machines are in use for conveying produce to market and other purposes in husbandry—wagons and carts—and of these there are several varieties. Wagons with four wheels, and drawn by two or more horses, are acknowledged to be best adapted for conveying great loads to a great distance, and that is their principal merit. For all ordinary purposes connected with husbandry, the one-horse cart with two wheels is preferable.

The Scotch cart, as it is called, is a most convenient and useful machine; and to add to its uses, it may be rendered serviceable for carting hay or straw by placing a movable frame on its sides, as represented here. The Scotch cart (without the frame) is suited for conveying any kind of material—dung, turnips, grain in sacks, &c.—and usually carries from eighteen to twenty-two hundredweight, when drawn by only one horse; with a horse in trace, the weight may be augmented. In Scotland, all grain for market is carried in these one-horse carts, and to any distance. On such occasions, one driver can take charge of two carts.

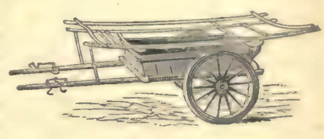


Fig. 12.

The following advantages of one-horse carts are well enumerated by Lord R. Seymour. 'A horse, when he acts singly, will do half as much more work as when he acts in conjunction with another; that is to say, that two horses will, separately, do as much work as three conjunctively: this arises, in the first place, from the single horse being so near the load he draws; and in the next place, from the point or line of draught being so much below his breast, it being usual to make the wheels of single-horse carts low. A horse harnessed singly has nothing but his load to contend with; whereas, when he draws in conjunction with another, he is generally embarrassed by some difference of rate, the horse behind or before him moving quicker or slower than himself; he is likewise frequently inconvenienced by the greater or less height of his neighbour: these considerations give a decided advantage to the single-horse cart. The very great ease with which a low cart is filled may be added; as a man may load it, with the help of a long-handled shovel or fork, by means of his hands only; whereas, in order to fill a higher cart, not only the man's back, but his arms and whole person, must be exerted.' To these just observations it need only be added, that in many parts of England there is a wasteful expenditure in horse-power, a couple of horses being often set to draw a clumsy wagon to market, containing a

load which could with the greatest ease be drawn by one horse in a less ponderous machine.

Every well-conducted farm establishment is now, or ought to be, provided with a variety of small but useful machines—for slicing turnips or potatoes, chopping hay or pease straw, bruising beans, pease, or oats, weighing-machine, &c.—all which, of the newest construction, are to be seen at the establishments of agricultural implement-makers. Utensils for cooking food for cattle, dairy utensils, and tools for manual labour, need not here be particularised.

SOWING.

In Scotland, the greater part of the cereals are sown broadcast. In England, on the other hand, they are frequently sown by drilling-machines; indeed, in the eastern counties, they are almost all sown by machinery. Experience has hitherto seemed to shew that the benefits of drilling are more marked in poor soils than in rich, on light than heavy land, in dry climates than in moist.

At the same time, it was not to be expected that drilling by machines should be so much followed in Scotland, owing to the hilly and irregular nature of its surface. It gained a footing however, pretty early in East Lothian, and we believe that the practice is still slowly extending.

Drilling is less advantageous in the case of late-sown spring crops, which grow up more rapidly, and keep down weeds. Up to a comparatively recent period, late sowing of cereals was very common in Scotland, and experiments on the drilling of these crops were not generally favourable. It is attended with greater benefits in early-sown spring crops, such as wheat and chevalier barley. On light and inferior soils, it is almost essential to the raising of these crops with any degree of certainty. This also applies to autumn-sown wheat on such soils.

The drilling of cereals effects a saving of seed, for if they are sown broadcast, more grain must be used, to prevent weeds springing up. In drilling, also, the seeds are deposited at an equal depth, and fewer of them are destroyed. When drilling has been adopted in Scotland, it has no doubt been customary to sow too much seed, a practice that should be avoided, as the crowding of the plants in rows stunts their growth, and renders the crops less productive. But the effects of using too little seed must likewise be guarded against, as this prolongs the life of the plants, causing them to tiller and produce more vascular stems, which are longer in ripening, and the quality of grain is inferior. Late-sown spring crops, therefore, should have a more liberal quantity of seed than early. On land in good condition, it is safer to sow two bushels of barley to the acre in the early part of March, than three by the middle of May.

It is also of importance to keep in mind that the land requires to be more carefully prepared in spring, when the grain is drilled. The roots of the plants being nearer to the surface, are more liable to be influenced by the drought, unless the comminution of the soil is carefully accomplished.

There are various kinds of machines for sowing grain. The English implement-makers have brought them to far more perfection than the Scotch. In the English machines, the seed is lifted from the box by cups attached to a barrel driven from the axle of the large wheels. The cups, emptying themselves into small hoppers communicating with the coulters by tubes, seem to be best adapted for effecting a regular flow of seed. The coulters, also, which form a bed for the seed, being jointed, move up and down, and permit of a uniform pressure, and, consequently, of an equality of depth at which the seed is deposited. The following sketch represents one of Garrett's corn-drills, which are in general use in the eastern counties of England.

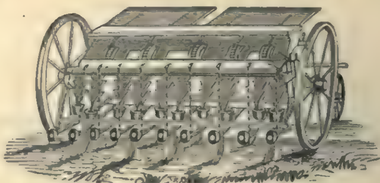


Fig. 13.—Garrett's Corn-drill.

One of the most important advantages of drilling cereals is the facility which it affords for keeping the crops free from annual weeds. In fact, the farmer has a much greater command over his crop when it is drilled than when it is sown broadcast. Weeds can be much more cheaply extirpated by the hoe than by pulling them by the hand. The great improvements that have recently been made in horse-hoes have rendered these implements of great service to the cleaning of drilled grain-crops. The following engraving

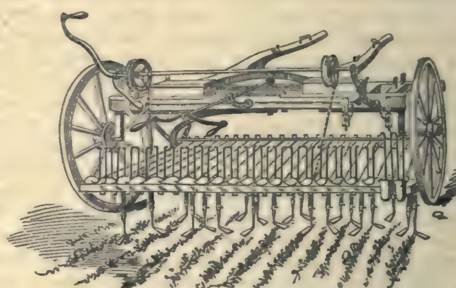


Fig. 14.—Garrett's Horse-hoe.

represents Garrett's horse-hoe, which, though somewhat heavy, is otherwise a most efficient implement.

DRAINAGE.

The vast amount of capital which has been expended in drainage within a quarter of a century, attests its utility and necessity. Before the introduction of furrow-draining, stiff and tenacious clays were of comparatively little value. They were cultivated at much expenditure of labour, and the crops which grew upon them were influenced to a great extent by the variations of the seasons.

Drainage by open ditches was no doubt the first mode of freeing land from superfluous water. The Roman agricultural writers mention the good results arising from covered drains, formed of wood and other substances, which served so far to render the land dry. More than a century ago,

a large extent of clay-land was drained at narrow intervals in Norfolk and Essex, by putting in brushwood and even straw in the bottom of the drains. The progress of this operation, which is now regarded in many soils as essential to economic culture, was slow and partial, until Mr Smith of Deanston reduced the practice to a system, and shewed the principles upon which its efficiency depended. Through the exertions of this advocate, furrow-draining soon became a *sine quâ non* in the culture of clay soils.

The great majority of practical men consider the line of greatest fall, or quickest descent, as the best for cutting drains in a field. This, it may be remarked, is also usually the direction for ploughing the land and forming the ridges; so that the drains are commonly put into the *furrows*, and hence the distinguishing appellation, *furrow-draining*. The smaller drains are conducted into larger or *main* drains, instead of each discharging its quota of water into the open ditch. This is rendered necessary, as the mouths of the smaller drains would be more liable to be choked up by the growth of weeds; while the collecting of water into main drains secures a fuller flow to sweep out any matters which might accumulate where the discharge is small.

Fig. 15.

The most efficient, and at the same time cheaply cut drain is one represented at fig. 15. It is made so that a pipe of a cylindrical form may be laid along its bottom, which should be of no greater width than what is necessary to its being securely placed.

Drains of this form are cut with a set of spades which are of different widths—the broader being used for taking out the top, and the narrowest for the bottom. The one which cuts the last spit is called the *bottoming tool*, and its introduction has effected a considerable saving in cutting drains.

Before the general use of pipes, stones were the common materials with which drains were formed. Mr Smith recommended that they should be broken so small that they might pass through a ring two inches and a half in diameter. From nine inches to a foot in depth was the quantity which was commonly put in. This was found to be a most efficient way of making drains; but unless the stones could be gathered from the fields, or quarried in the neighbourhood where they were used, an immense amount of labour was involved in filling them.

Fig. 16.

When tiles and pipes were first used, it was even thought necessary to have some gravel, or small stones, placed above them in the drains, for the purpose of enabling the water to find its way into them, as seen at fig. 16. It was soon found, however, that tile-drains were quite as efficient without any stones or gravel; and that they were less liable to be choked up, as the clay or earth acted as a filter in preventing the intrusion of any kind of solid matter.

Many kinds of tiles and pipes have been tried, but the cylindrical form is now most used. At one time, a bore in the tile of an inch in diameter was thought sufficient, but two-inch tiles are now preferred. They are usually made about fifteen inches in length. The continuity of the drain is sometimes maintained by *collars*, but now their utility is, to say the least, much doubted.

Much discussion has taken place in regard to the proper depth of drains, as well as the distance at which they should be placed. Mr Smith at first advocated the making of drains from two and a half to three feet deep, and at intervals of from ten to forty feet, according to the nature of the land. Experience, however, has been gradually favouring deeper drains, at wider intervals. Mr Parkes went the length of recommending a depth of from four to six feet, at intervals of from twenty-four to sixty-six feet. Even on the most tenacious soils with subsoils of *till*, few now think of having drains less than three feet in depth, though the distance apart should not in many cases be more than from fifteen to eighteen feet.

The mere tenacity of clays is not the element which determines the depth of drains, or the distance at which they should be placed apart. It is now well understood that the success of draining by pipes depends upon the fissures which are produced in the subsoil by the droughts of summer never entirely closing up; and thus minute channels are formed which lead the water into the drains. The coarse tenacious clays which are to be found in the chalk-valleys of England *crack* readily by the droughts, and form deep fissures, which render them comparatively easily drained. On the other hand, in the moist climate of Scotland, the subsoils which are of *till* are long in cracking; and the drains in such land should not be so deep, and at shorter distances apart. As the properties of clays become better understood and classified, practical men will soon come to be more at one in regard to this important point connected with the economy of drainage.

The principal advantages of drainage are, the deepening of the staple soil and rendering it more friable, so that a superfluity of water which would cause the formation of those chemical compounds that are found in stagnant water is prevented. The greater depth of mould, and more perfect culture, render the soil more absorbent of moisture in dry periods of weather. As crops can usually be sown sooner on drained lands, they also ripen earlier, and produce more abundantly. In short, while drained land obtains a greater capacity for moisture and manure, it imparts to plants greater capabilities for economically working up the materials which they find both in the soil and atmosphere, seeing they are maintained in the most healthy conditions of growth.

Green Crops.

Grasses, as seen in perfection in rich lawns or meadows, are the most beautiful crops that grow. The constant carpet of verdure which these present in England, is owing to the great number of varieties which come to perfection at different periods of the year. In sowing out fields for permanent pasture, we do well to take a lesson from nature, and sow a mixture of grasses which are valuable, and at the same time indigenous to the soil; for although those grasses which are best suited to the soil will often, in a series of years, take possession of it, yet time is gained by anticipating nature.

The common varieties of annual and perennial rye-grass are sown when the land is under a system of rotation, and when the fields only remain for one or two years in pasture. These are valuable plants in all the moister parts of the British Islands, but in the south-eastern parts of England they yield little leaf; and the droughts encourage the production of stems which are not relished by stock. For this reason, less benefit is derived from two years of pasture in England than in Scotland.

Italian rye-grass is now grown to a considerable extent in Britain: it is not a good pasture-plant, however, as it grows thin upon the ground, and being shallow-rooted, does not thrive, unless the soil is shaded by its own leaves, which in some measure perform the same ends as pulverising the soil, and rendering it more absorbent of moisture. A liberal dressing of manure in early spring, by sending up a mass of vegetation, which protects the soil from the evaporating influences of the weather, renders the crop less dependent on a supply of rain. Italian rye-grass, for this and other reasons, is better adapted for cutting than for pasturing. It is grateful for liberal treatment, as no other cultivated plant seems to have greater capacities of growth.

Grasses being usually sown out with a grain crop, grow little for a year; their roots have time to run through the soil in search of the earthy matters which the crop requires. Phosphates are therefore seldom used for grass, unless the soil is very deficient of these substances. Nitrogenous manures are thus best suited for all descriptions of grasses.

Clovers grow most freely upon calcareous soils. In the rich marly loams of France, the various varieties of red clover produce fine crops, though much more frequently sown than in Britain. On the limestone gravels of America, red clover is sown every other year, and the land shews no symptoms of clover-sickness. It is on the non-calcareous formations of Scotland that we find this plant so uncertain and fickle in its growth. This we attribute to the want of calcareous matter to correct the vegetable accumulations which take place in the soil, and interfere with the healthy functions of the roots.

Clovers, like grasses, are most benefited by nitrogenous matter, if the soil is favourable to the healthy functions of their roots. A rich dressing of farm-yard manure will sometimes so far counteract clover-sickness by affording the crops a ready supply of earthy matter, which they cannot otherwise absorb, to carry on the assimilating processes in a healthy state. We have known instances of a dressing of two hundredweight of guano, applied to an acre of young clover layers in autumn, after the corn-crop was removed, impart such a vigour to the plants, that they grew luxuriantly next summer, while the clover entirely disappeared from the rest of the field. From the roots of clover running deeper into the ground, nitrogenous manures are most advantageously applied in autumn, as they tend to strengthen the plants, and enable them better to withstand the deleterious conditions by which they are sometimes surrounded.

From red clover sending its roots deeply into the ground, it is comparatively independent of moisture in dry climates. The same observation applies to sainfoin and lucern, which are invaluable crops in southern latitudes where the soil is calcareous. All these plants, like grasses, maintain a large surface of fresh leaves exposed to the atmosphere, and therefore restore to the soil a supply of vegetable matter, when it has been wasted by tillage.

Beans are only grown on the first-class land in Britain. This arises from the crop requiring a deep soil into which it can send its long tap-roots, and obtain the necessary supply of moisture for its large surface of leaves exposed to the atmosphere. Being an annual, and sown early, it must have a full supply of manure, unless the soil is very rich. The most general plan of raising this crop in Scotland is to sow in drills or ridges, twenty-seven inches apart, into which an allowance of farm-yard manure has been placed, the common allowance of seed to the acre being four bushels. Where the land can be manured and ploughed in autumn, it has been found that to grub the soil in spring, and drill the seed on the flat in rows sixteen inches apart, and using only two and a half bushels of seed per imperial acre, the crop is much larger and the ground cleaner. By this method, in dry weather, the crop closes sooner and keeps the land clean, while, in growing seasons, each stalk being single, the pods are found to set better. By using Garrett's Drill, five rows are sown at once, and by using the horse-hoe adapted to the same number of rows, the land can be easily kept clean without hand-labour, beyond pulling any tall weed growing amongst the grain.

Pease are greater favourites in warm and dry districts than in wet and cold ones, where they are more difficult to harvest. They are frequently sown along with beans; but they do not occupy an important place in the rotations of well cultivated districts, since the general introduction of turnips.

Turnips, for the feeding of stock, arrive at great perfection in this climate. Being sown, however, in that part of the rotation which was formerly occupied with a bare fallow, they form a most expensive crop. In fact, it is not only designed that they should answer all the ends of a bare fallow, but through their growth, and by being usually consumed by stock, an accumulation of vegetable matter takes place on the farm. By this means, a larger quantity of the more valuable produce, such as cereals, may be raised and disposed of.

Turnips are divided into various classes, in each of which there are several varieties. The Swedes, belonging to the most valuable class, have been largely cultivated since the introduction of light manures. White turnips are sown in Scotland early in season; but in England they are usually put in very late. Yellow turnips are the principal class raised in Scotland, as they seem better suited to the low temperature.

In the south of England, Swedes are sown from the end of May to the 1st of July; so late sowing, however, is only practised on light soils. White turnips are sometimes sown there so late as the 1st of August. Swedes and white-globe turnips are sown in Scotland from the 1st of May to the 10th of June; and all the yellow turnips should be put in ten days after the latter date.

The land should be thoroughly cleaned and

pulverised before turnips are sown. It is usually drawn up, by the double-moulded plough, into drills or ridges, about twenty-seven inches apart, into which the manure is spread. The manure being covered by 'splitting' the ridges by the plough, the seed is sown by machine on their crests. This enables the young plants to obtain a ready supply of manure, which promotes a rapid growth. When the leaves are about two inches high, Tennant's grubber should be used betwixt the rows; and thinning may then be commenced. This is done by hand-hoes; and the work being light, it is frequently performed by women and boys. Three expert hoers may go over an acre a day. The crops are frequently drill-horse hoed or grubbed during their growth. Earthing up the turnips by the plough is less frequently practised than formerly, excepting upon stiff clay soils.

To raise maximum crops of turnips, the soil must not only be well cultivated, but highly manured. All those varieties which are early sown should be most liberally dressed with matters yielding carbonic acid and ammonia, for the simple reason, that the longer a plant lives the more it can digest and assimilate; and further, all those varieties whose growth is extended over the longest period, should have the manure supplied in the most carbonaceous form, which is the best means of slowly yielding up the active elements as the crops require them. Farm-yard manure is best adapted for prolonging the growth of turnips in autumn; and their early growth is best promoted by guano and other soluble nitrogenous manures.

Phosphoric manures are largely and efficaciously employed in raising late-sown turnips. Except on rich soil, these manures can never be relied upon to raise *maximum* crops of turnips, which require more ammonia than any of the cereals. It ought to be borne in mind, however, that in nineteen cases out of twenty in which phosphates are beneficially applied to the turnips, there is really abundance of phosphoric acid diffused through the soil; the necessity of an artificial supply is owing to the small seeds of the turnip requiring a concentrated dose placed within reach of their rootlets, so as to promote their rapid development. Phosphates enable the turnip-plant to form roots and leaves, without which it cannot appropriate the nutrient matters existing either in the soil or the atmosphere. Medium crops of turnips may often be got by dressing with superphosphate of lime, in the middle of June in Scotland, when the crops have little time to grow; but this manure, unless combined with matters yielding ammonia, cannot be relied upon to raise a crop of turnips which is sown in the middle of May.

Turnips are either consumed by sheep on the fields in which they grow, in grass-fields, in fold-yards, or feeding-houses. In the vicinity of large towns, they are sold to cow-feeders. This department of agriculture will be treated in CATTLE AND DAIRY HUSBANDRY.

After having the roots and leaves cut off, the bulbs of the turnips are usually stored in heaps about eight feet in width, and piled up as high as they will lie on this breadth of base. They are covered with straw, which is fixed on with ropes, or sometimes a spadeful of earth is thrown on, to prevent the wind blowing it off. Earth, however, is so far objectionable, as it prevents the gases from escaping, and encourages fermentation. The most common error is putting too great a quantity of turnips together, for the heat ferments and the roots decay. Perhaps the most simple and best mode of storing turnips is to lay them out in a field adjoining the farm-steading, in large heaps, level on the top. The only precaution necessary is, not to make the heap more than two feet in depth. A quantity of loose straw is thrown over the top of the heap, which the first shower of rain is sufficient to beat down, so as to require no further fastening. When stored in this way, turnips resist the frosts better than when piled up in pits, which are more exposed to the wind; and they are also less liable to sprout in spring, as the straw keeps them moist and cool. In storing turnips which are to be early consumed, care must be taken not to cart them in when in a frozen state, or covered with hoar-frost.

Mangel-wurzel.—The productive powers of the Swede are more limited in England than Scotland, or, in other words, larger crops can be grown in the latter. Any deficiencies, however, which exist in the root-growing capabilities of the southern climate with respect to turnips, are amply made up by its adaptation to the growth of mangel-wurzel.

The plant having small seeds, and being sown fully one month earlier than the Swede, must be liberally supplied with manures yielding phosphates and ammonia. With the exception of Italian rye-grass, or the cabbage, no other plant is capable of working up or assimilating a greater quantity of food in a season. The capacity of the mangel for manure is seen when planted on the richest garden-ground, or on spots from which dunghills have been removed. In these circumstances, turnips will only grow to leaves and stems, while mangel will produce large roots. In highly manured land in the south of England, very large crops of mangel are raised, far outweighing the produce of Swedes in this country.

Mangel-wurzel is an inferior plant to the Swede in the climate of Scotland, for, even with the most liberal treatment, the crops are comparatively light. In our colder climate, also, the plants have a much greater tendency to seed than in the south. In the inferior produce of the mangel, and this tendency of the plants to seed, the effects of the lower temperature of Scotland are more clearly exhibited than by any other cultivated crop.

One of the chief elements that hasten the seeding of plants is a scanty supply of food. The growth of the cabbage, for instance, in its leafy state, is only protracted by a liberal allowance of manure. Indeed, the abnormal supply of food that vegetables obtain in their cultivated condition, is the principal influence which alters their habits of growth. Liberal manuring, and a soil of good physical capacity, are well known to have the effect of protracting the period of bulbing in turnips; while the opposite conditions, light manuring and a dry soil, cause the plants to flower.

It is only a modification of the same principle that we have stated above that is in operation, when mangel flowers in summer in colder climates. Plants, like animals, may be starved by cold as well as by a want of food. A want of moisture, also, has the effect of making vegetables form

flowers. Dry and cold weather, conjoined with a short allowance of manure, have a great influence in hastening the seeding of plants.

The principle of a higher temperature delaying the period of flowering in plants, is strikingly exhibited in the case of our cereals, inasmuch as wheat, barley, oats, and rye have no tendency to seed when sown in summer in southern latitudes.

Potatoes now form a more important crop on almost all arable farms, than they did twenty-five years ago. The immense increase of population in London, Liverpool, Manchester, and Glasgow, and generally in all manufacturing towns, has created an extensive market for this vegetable, while the development of the railway system has facilitated their cheap and rapid carriage. It is not too much to say that the present rents of farms in the Lothians of Scotland could not be paid unless from the profits of potato-growing. In years when the crop is unusually plentiful, and consequently cheap, the roots are found to be extremely useful in cattle-feeding, though prejudicial to sheep unless sent quickly to the butcher. Experienced feeders of cattle consider them worth from thirty shillings to forty shillings per ton. The usual period of planting in the British Isles is from the first of March to the middle of May, but the earlier the better; while the harvesting of the late varieties begins in October, and is seldom finished until the close of November. It is customary to plant eyesets, or cut pieces of potato, each having an *eye* or point of germination. Small potatoes, with some of the eyes destroyed, are approved of by many English growers; and in dry seasons they certainly afford greater security against blanks than cut sets, but the latter generally produce a larger proportion of full-sized marketable potatoes. The quantity of seed required is about half a ton per acre; kidneys or varieties planted whole require more. The sets are planted at a distance of 12 inches apart in drill-furrows made by the double-mould-board plough 28 inches wide. A heavy dressing of farmyard manure is sometimes applied to the land in the autumn, but in general is spread in the furrows previous to planting, and supplemented with guano or artificial manures; no crop repaying so well for abundance of manure. Indeed, potatoes cannot be grown profitably unless highly manured. Potatoes usually take the place of beans in the six-course shift; but profitable crops are frequently obtained after two or three years' lea, particularly where stock have eaten large quantities of linseed-cake. Of course a proportion of light manures is applied. The lea should be turned over to the depth of 12 inches at least, which is done by a furrow turning over the sod, a plough with three horses following covering it up. Where the turnip-crop has been consumed on the ground by sheep, which have had at some time an allowance of linseed-cake, potatoes may also be taken with advantage by the aid of light manures alone. The wheat-crop succeeding the potatoes is invariably fine, and the clover-grass thereafter is invariably superior; in fact, there is no better plan for at once making land rich and clean. After the plants appear above ground, they are as frequently grubbed and hand-hoed as may be required to keep the ground loose and free from weeds, and finally earthed up with a double-mould-board plough, to cover all the tubers, and prevent them becoming green. Being very susceptible of frosts, potatoes must be stored carefully in narrow pits covered with straw and earth. Large pits must be avoided, as early in the season the roots are apt to heat, particularly when dry and free from earth, and at no time should the pits be wholly covered with earth for at least a fortnight.

White Crops.

Wheat is the most important of all the cereals, and we believe it grows over a wider range of latitude than any other plant. In Egypt, it is raised under the Tropic of Cancer, and on the continent of Europe as high as the 60th parallel. It is right to observe, however, that this extreme range is obtained by its growing in the one country in summer, and in the other in winter. Indeed, it is not a plant that requires a high mean temperature before it puts forth its ears; it even exhibits little tendency to produce seeds if sown during the heats of summer in France or America.

In Britain, a great number of varieties of wheat are cultivated. Spalding, Kessingland, Lammas, Browick, red wheats, are great favourites in the dry climate of England, as they yield more grain than any of the white varieties. The farmers consider that they are usually as well paid by the larger quantity of grain, though the quality is inferior. Velvet or woolly-eared Hopetoun, Hunter, red chaff white, red strawed white, and Fenton, are common varieties in all parts of Britain. April or awny wheat is sown on some inferior soils in Scotland, where it is quite as sure a crop as barley, and the straw is as good for fodder.

From six pecks to two bushels of grain are usually sown by the drill in the south of England. Less than the latter quantity is seldom sown in Scotland; and when sown on the common furrow, three bushels is the common allowance after green crops. Spring-wheat should be sown rather thicker than autumn, to hasten on the crop to maturity, and to promote a fine sample.

Wheat is generally sown in the southern and eastern counties of England after clover lea. In all dry climates, the decaying matter which clover-roots afford seems to be best adapted for feeding the wheat-plant during the long time it is in the ground. It ought to be constantly borne in mind that, in manuring a plant, we should be guided by similar principles as in feeding an animal. Theoretically speaking, every one must allow that no more food should be supplied to plants or animals than they are capable of daily digesting or assimilating. Manures, therefore, should be of such a nature as to afford nourishment to plants during their whole period of growth. Plants which do not grow rapidly, should be supplied with manures that slowly yield up their active substances. Autumn-sown wheat, therefore, in dry climates is best manured by a clover sod.

As a general rule, the growth of autumn wheat is most economically promoted by carbonaceous substances; such as clover roots, the refuse of the manures which have been applied to green crops, or by rape cakes, and inferior qualities of guano, which only yield up their ammonia during the growth of the crop.

With spring-sown wheat, a different course must be followed. Its growth being more rapid, the

ammonia should be in a form that can be more readily assimilated, and hence Peruvian guano is the best application for this crop. The most soluble manures, on the other hand, such as nitrate of soda, are best fitted for top-dressing wheat in spring, for the rapidity of growth which ensues in early summer enables plants to digest a larger quantity of food in a given time.

The value of manures is rated by the quantity of ammonia (or nitrogen) which they contain. But so much is this principle held in abeyance to the *form* in which this element exists in manures, that even before the recent rise in the price of guano, nitrate of soda was largely used for top-dressing wheat, though nitrogen in this form cost the farmer double the price per pound that it did in Peruvian guano. Rapid growth and soluble manures must go together.

In all hot countries, the common varieties of wheat can only be sown with advantage in winter; even in the eastern counties of England, where the range of the thermometer is considerable in May, these varieties do not succeed so well when sown in spring as they do in Scotland and the western counties of England.

From the circumstance of the growth of wheat being extended over a longer period than any of the other cereals, and of its growing in a colder season, it must be more liberally manured with substances which slowly yield up the nitrogen they contain. For this reason, it has always been regarded as a very exhausting crop, requiring more manure than any other. But owing to the fact of the soil requiring to be dressed with substances that only slowly yield up their active principles to the crops, the soil cannot be exhausted by crops of wheat to the same degree as by crops of inferior grains, which require less manure, but which leave less in the soil, and thus really exhaust it more. Turnips grown by market-gardeners require a great deal of manure, and are justly regarded as exhausting crops; but from the large residue of manure left in the soil in the mere forcing of these crops, the land is still left in a richer state than when crops of turnips are grown by superphosphate of lime. Instead of proprietors of land restricting the quantity of wheat on their farms, they would do well to encourage its extension, seeing the growing of wheat is actually a test of the good condition of the soil.

Wheat is liable to certain fungous diseases, as, for example, smut, mildew, and rust. The last two it is not so much in the power of the farmer to prevent as the first; they are more common in England than in Scotland. Early or thick sowing tends to impart conditions which are unfavourable to the appearance of these diseases. Smut is best prevented by watering the wheat with a solution of sulphate of copper—one pound of this substance being sufficient for half a quarter of wheat; it should be dissolved in as much water as will thoroughly wet the grain, which, as soon as dry, may be sown.

Rye is usually grown on light sandy soils, and requires less care than wheat. It is frequently sown along with winter tares in England to be cut for soiling, and when sown on the wheat stubble, is extremely useful as food for breeding flocks in spring, as it comes forward earlier than tares, and affords good pasture when other substances are scarce.

Barley.—There are several varieties of this grain cultivated in Britain: the early English, Annat, Stirlingshire, chevalier, and *bere*, are the most common. This grain grows best upon a rich mellow loam, moderately retentive, where the culture has been careful. It rarely succeeds where the soil is stiff and wet. On the heavy clay-soils of Essex and Suffolk, excellent crops of barley are got after summer fallow. The ground being ploughed up in autumn, the mould which is pulverised by the frosts affords a fine seed-bed. The surface is usually scarified before the seed is sown by drill. An intelligent agriculturist, who farms heavy clay-soils in Suffolk, writes: 'When new year has commenced, the Suffolk plan is never to let a favourable opportunity escape for drilling barley, if the land is prepared.' When land is in good condition, early sowing is to be preferred, as heavier crops and finer quality are thus obtained.

On the light soils of the southern counties of England, barley is usually sown after the turnip-crop, which is generally eaten on the ground by sheep. After the land has been trodden, it must be carefully prepared by two or more ploughings, rollings, and harrowings, to pulverise it, and render it more retentive of moisture. In the dry climate of Norfolk, the farmers expend a great deal more labour in preparing the land after turnips, than they do in the moister climate of Scotland, where turnip-land is rarely ploughed more than once. Owing, also, to the greater heats and droughts in the south of England, good quality of barley is rarely got when sown after the middle of April.

It is much easier to over-manure barley in moist climates than wheat; hence the latter is more frequently sown in the western counties after turnips eaten on the land by sheep. Much land is well adapted for the growth of the finest quality of barley along the east coast of Scotland. Barley is now sown in Scotland as soon as the land is in a fit state to receive the seed. On rich and dry soils, barley is rarely injured by spring frosts; it is only on weak soils, or such as are out of condition, that complaints of this nature are heard of.

On many of the trap-loams in Scotland, barley is sown after wheat; in this case, it is generally sown late, as the more genial temperature acts as a compensation for a richer soil. This is in accordance with the principles enunciated under the head of the Meteorology of Agriculture. Early-sown barley is best manured by Peruvian guano, as plants growing in the colder season demand a more liberal supply of food. If barley is sown in May, less ammonia should be applied, as at that season the crop can rely to a greater extent upon the atmosphere, if it obtain a ready supply of phosphoric acid. Thus superphosphate of lime is generally of little use when applied to barley sown in March, but has often good effects when sown in the end of April or May.

The six-rowed variety of barley, called *bere*, is now chiefly confined to the northern counties of Scotland. It is the most hardy of all the kinds of barley, and being stiffer in the straw, it is not easily laid by rains or over-luxuriance.

Oats.—Of this grain there are many varieties, which our space prevents us from particularising. The potato-oat is an early and productive variety on low and rich lands; indeed, it has gradually

extended as the fields have been better manured. Though the oat is usually considered to thrive best in moist climates, the level land along the sea-coasts of Scotland, such as in the plains of the Lothians, produces the most grain and finest qualities. Many varieties are suited to climates which are too wet and cold for other grains. The oat is a grosser-feeding plant than any of the other cereals, and can be more freely dressed with nitrogenous manures. In the rotation, oats succeed grass or clovers, and in moist climates, leave the land much cleaner than when wheat is sown. From four to five bushels of seed to the acre are sown broadcast, and from three to four when drilled. The usual time of sowing is from the beginning of March to the end of April. If the land be in good condition, the earlier the better.

Haymaking.—When the grass has arrived at or near its full growth, but before the seed is perfected, it should be cut down. If not in a fit state to be cocked the first day after cutting, it should be put into small handcocks as soon as its state of dryness will allow; from these it should be gathered into larger ones, and when its condition permits, put into tramp-ricks. Let it be remembered that the less the hay is exposed to the sun, the better is its flavour and strength. In wet seasons, the utmost care will be required not to stack the hay while moist; for then, like moist sheaves of grain, it will heat, and either burst into a flame, or be seriously damaged in quality. The criterion for good hay is, that it should be greenish in colour, be perfectly dry, and possess a sweet odour and saccharine taste.

REAPING—HARVESTING.

The ripeness of grain is shewn by the straw assuming a golden colour from the bottom of the stem nearly to the ear; or when the ear begins to droop gently, the corn may be cut. Although the straw may be green from the ear for some distance down the stem, yet, if it be quite yellow at the bottom, and for some distance upwards, the grain requires no further nourishment from the earth, and if properly harvested, will not shrink. These indications of ripeness may suffice for wheat, barley, and oats. In peaty soils, however, the ears of oats and barley usually ripen before the straw, which often requires to be cut in a green state.

Reaping.—Since the Exhibition of 1851 in London, the reaping of grain by machinery has attracted a great deal of attention. The American reapers exhibited there shewed that the mode of cutting the grain might be simplified, though these machines were in a comparatively imperfect state, and not fitted for the requirements of English agriculture. The following wood-cut represents the cutting part of Hussey's reaper. The cutters are set in motion by the machine as it progresses.

Bell's original reaper was a much more perfect machine than any of the American machines, as it laid down the corn so that it could be easily gathered up for binding. The liability of the cutting-knives to get out of repair was its principal defect. It was soon discovered, however, that Bell's might be greatly improved by M'Cormack's mode of cutting. A large number of machines were made on this combination, and known as Crosskill's and Bell's reaper. These, however, have long been superseded by much lighter, if not more efficient implements; many are now

Fig. 17.

drawn by one horse only, and all of them are easy work for a pair. Reaping-machines have now fairly displaced hand-labour either by hook or scythe, except so far as cutting round the fields, to enable the machines to begin working. It was one great advantage of Bell's reaper that it required no assistance before it commenced, but opened out a path to itself. Reaping-machines may be divided into two classes—namely, self-delivery and manual-delivery machines. The last, at present, are the most common, owing to the great desire evinced by farmers for machines of the utmost simplicity. Still, the self-delivery machines make way; they save the wages of a working-man in harvest, as one boy or lad is all that is required to drive the horses and guide the machine. Another great advantage they possess is, that the grain is thrown off in sheaves, sufficiently apart from the standing crop to give room for the horses continuing their labour; while the manual-delivery requires the cut corn to be removed before it can again go on. It is certainly better as a rule to bind and stook the corn as it is cut; but with much ripe grain, and a scarcity of labour, it often proves highly advantageous to cut whole fields before it is possible to tie or stook a single sheaf. In practice, it is found the best plan to cut grain only one way, and that directly against the lie of the straw. The length of the ground is marked off in divisions, in proportion to the number of hands employed, which may run from nine to fifteen to each machine, according to the bulk of the crop. Two people, generally boys or women, make the bands, and place the sheaves in them, while one man binds and stooks the grain. When two or even three machines can be used at one time, the space allotted to each binder and his two assistants is shorter, and consequently having to walk a less distance, they are enabled to do more work. On an ordinary farm, it has been found that the number of hands required for harvest-work has been reduced betwixt a third and a half; and in many instances it is wholly done by the ordinary staff of labourers on the farm, aided only by the resident women and children. To say nothing of the reduced expenses from the employment of reaping-machines, the relief of the farmer from intense anxiety as to the conduct of people he never saw before, is almost of itself a priceless boon.

Grain-crops in the Lothians have generally the stooks made of eight sheaves, placed in two rows, the head of each sheaf leaning upon the opposite one. In damper climates, the stooks are frequently formed with ten or twelve sheaves in a row, and covered with two head sheaves, which to some extent saves the corn from rain; but when thus treated, the grain is longer of getting into condition; so with settled weather, the head sheaves may be judiciously omitted. Wheat is frequently ready for stacking within eight days after being cut, but, as a rule, oats and barley require nearly double that time, particularly when the straw is mixed with strong clover plants. When this is the case, leaving it unbound one or even two days after it has been cut, greatly hastens the drying process. However, it always requires the greatest caution on the part of the farmer to ascertain whether his crops are in a proper state for being carried to the stack-yard. The best way of judging of this is to take out a handful from the centre of a middle sheaf on the lea side of the stook, repeating this on several parts of the field, and if the knots or joints of the straw are dry and shrivelled, the crop may be led home with safety. It must be remembered that while not a moment should be lost in securing grain after it is really ready, the loss from heated stacks by the discoloration of the grain, and the rendering of it unfit for man and beast, is perhaps annually as great as the loss from weather; it is better it should be spoiled in the field than the stack.

Stacking.—When the crop is thoroughly dry, it is led home to the stack-yard on open spar-built carts, and built into stacks so constructed as to afford complete shelter from the weather. The stool or bottom upon which the stack stands was formerly made of loose straw or brushwood; but in the best managed farms, it is now the practice to construct the stacks on stands made of stone or brick, or upon pillars made of stone or cast iron, sparred across with wood or iron. These stands are formed so as to prevent the access of vermin, which is calculated to effect a saving of two bolls in thirty; and many have funnels from the top to the bottom of stacks, to admit a free current of air. In Scotland, the stacks being mostly round, a sheaf is first placed on its butt-end, in the centre of the bottom or stand; around this, others are placed, also upright, but with a slight inclination of the head inwards, until the stand is nearly filled. The stacker then places a layer of sheaves horizontally on the outside of these, lying on their sides, the ear-ends inwards; and pressing them together with considerable force, he continues to lay on rows until the outside sheaves are as high as those standing on end. The whole stack is filled up in nearly the same manner, the ear-ends of the sheaves being always inwards, with a regular inclination downwards and outwards to their butts, and the centre of the rick being higher, and not so compressed as the outside. Proper attention to the sloping of the sheaves is necessary from the foundation of the stack, that rain may not run into, but from it, and particularly so at the intake of the inner layers, that part being always left more open. When this is done, the stacker sets up an outside circular row of sheaves, having their butt-ends projecting a few inches beyond the body of the rick; after which the outside layers come gradually inwards, until the roof is drawn to a narrow circle, and finished with a small bunch of straw, over which a straw-rope is thrown, the ends of which are fastened on opposite sides of the stack. This makes a round top to the stack, but it saves time, and thus expense in both building and thatching; while the top remains always unbroken by rooks or other vermin, which frequently do much mischief. When carefully built and thatched, a stack will completely keep out rain, and be quite secure from high winds. Materials for thatching and straw-ropes should always be made before harvest, so that no delay may arise from this in the event of wet weather.

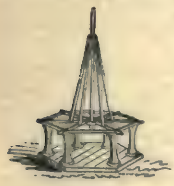


Fig. 18.

Stacks are sometimes constructed in England on a timber platform raised upon stones, and over the stack the framework of a perfect barn is placed, which can be either tiled or thatched. This is said to afford greater security to the crop, and to be less expensive than annually thatching. The price of erection is said to be comparatively trifling, when the convenience of such buildings is considered; and they have been known, when well put up, to last for thirty years.

Thrashing is either performed with the flail or the thrashing-mill. The use of the latter we by all means recommend in preference on arable farms of above 100 acres in extent. The machine may be driven by water, horse, or steam power, according to circumstances. Several improvements have been made on thrashing-mills since their first invention. The unthrashed corn is now made to pass through two revolving rollers, while it is acted on by beaters placed lengthwise upon a large cylinder or drum, which moves at the speed of 2500 feet in a minute. The great essential in thrashing is to have regularity of motion, and the grain to be equally fed into the rollers. One man should be employed to feed in the corn; one man, or two boys, to carry the sheaves; and a woman to untie and place them on a table near the feeder. Other persons are employed in raking and carrying the thrashed straw to the straw-house, where it is built. When the machine is driven by steam or water, it is generally the case that one or two winnowing-machines, according to the power employed, are attached to the thrashing-mill; and thus the expense of preparing the grain for market is considerably lessened. A powerful machine will thrash from 200 to 300 bushels in nine hours; and allowing for wages and wear of machinery, the expense of thus preparing grain for the market is under one penny per bushel.

Various improvements in thrashing grain have been introduced. The small, high-speed beating or rubbing drum, so much in use in England, has lately been introduced into Scotland; and, as its construction is better understood, it is giving greater satisfaction. On the large farms in England, portable steam-engines, though more costly than the fixed, are preferred by farmers who have yards for feeding cattle in various parts of their holdings, for the purpose of effecting a saving in the carting out of the manure. Of late years, numerous individuals make a living by travelling the country, and letting out portable machinery

on hire in both England and Scotland. As they are without feeding-rollers, and do not break the straw like the common beater drums, they are in great demand for the making of thatch.

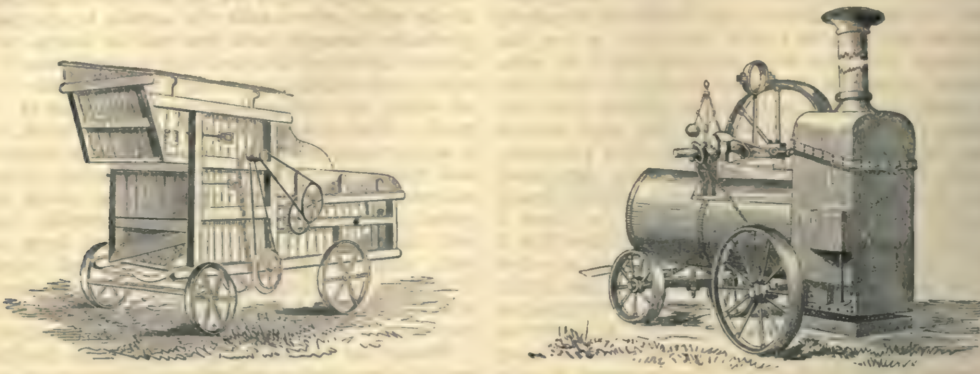


Fig. 19.—Clayton and Shuttleworth's Thrashing-machine and Portable Steam-engine.

Winnowing is a process performed by the aid of wind, by which the chaff of corn is separated from the grain. Winnowing-machines, or fanners, as stated before, are frequently attached to thrashing-mills, and they are a necessary appendage to every farm, either in conjunction with the thrashing-mill, or separately. Some farmers winnow their grain by hand-fanners, but a steadier motion when driven by machinery has lately been secured; so this mode increases, and the grain is at once fit for market. By the process of winnowing, chaff, bits of straw, the seeds of weeds, and other refuse, are separated from the grain; and it is a wise precaution to boil the latter before putting them on the dunghill, which will effectually destroy their vegetative powers. The different qualities of grain are also separated from each other, by which it is rendered more valuable than when the good and bad are mixed together. The thorough cleaning and dressing of grain are of great importance to the farmer; and he will find it to add to his profit in the end to have this effectually done.

Barley undergoes a process called *hummelling*, by which the awns are broken off from the grain. The machine is composed of a vertical spindle inclosed in a cylinder, and furnished with arms which act upon the grain. It is sometimes attached to the thrashing-mill, and sometimes driven by a separate power. The grain is put in at the top of the cylinder, and as it passes through, the awns are broken off by being struck by the arms attached to the spindle. A more simple process is, after the barley is thrashed, to take off the head of the drum, and put on another cover of tin, perforated with small holes about three-sixteenths of an inch wide. The barley is passed through the rollers, and by this the awns are rubbed off.

After being dressed and made ready for market, grain should be kept very dry, in a granary free from damp, and impervious to the incursions of vermin. It is, however, the best plan not to thrash grain till it be required for market, because it loses in weight, or shrivels in bulk, by keeping. It also loses in weight, though to a much less extent, by being kept long in ear in stacks; and therefore the sooner grain is thrashed and carried to market, the greater will be the return, supposing there be no rise in price.

ECONOMY OF ROTATIONS.

The majority of the crops which have already been noticed are cultivated to a greater or less extent on most farms; but peculiarities of soil and climate, distance from markets, besides many other circumstances, conspire to render particular crops more prominent objects in the rotation of one district than another. Indeed, the practical economy of British rotations is a most interesting subject, though one that has received comparatively little attention. Our space being necessarily limited, we shall only discuss the more important heads.

Norfolk has long been celebrated for its agriculture; and though the art has made great advances within the last century, it is curious that the rotation of crops in that county has undergone little change during so long a period. Mr Caird has fallen into the common error of attributing the founding of the Norfolk four-course rotation—turnips, barley, clover, wheat—to the late Lord Leicester; whereas the truth is, this rotation was generally practised long before his lordship became a farmer. Mr Coke only came into possession of his estate in 1776; but Arthur Young made his celebrated tour through Norfolk six years before this date, and he then gave the following account of this rotation: 'It is a noble system, which keeps the soil rich, though some farmers depending on their soils being richer than their neighbours'—for instance, all the way from Holt by Aylsham down through the Flegg Hundreds—will *steal* a crop of peas or barley after wheat; but it is bad husbandry, and has not been followed by those who have made fortunes.' In recommending a change in this system of cropping, Arthur Young shews us that *high farming* had already taken hold in Norfolk. The modern improvements that have taken place have not been in the direction which this accurate observer anticipated. He writes: 'If I may be allowed to hazard an idea on this point, I should venture to condemn the ploughing up the clover the first year, and for these reasons: it is exhausting the land more; two crops of corn in four years exhaust much more than two in five years; hence appears to me the *modern* necessity of buying

oil-cake at two guineas an acre.' This is admirably stated, and shews that, at that period, money-making farmers had adopted the shorter and intensified system which was afterwards carried out by Lord Leicester.

It is rather singular, however, that Lord Leicester, as it would appear, had been struck with Arthur Young's reasoning, and had pursued the very course he recommended; for, in 1783, Arthur Young paid a visit to Holkham, and his lordship was following the five and six course shift, or of having two or three years in grass. The objections to this system were, that it allowed the land to become foul, and three or four ploughings instead of one were necessary to bring it into a proper condition for wheat. Commenting on this practice, Young again writes: 'On our good lands we never think of giving more tillage than one ploughing, and get as fine crops as can be seen; now, the necessity of tearing a loose soil to pieces, the fault of which is too great looseness, while no such necessity exists on much stiffer soils, appears to be quite a paradox.' This extra cultivation of the grass-land, however, has always been found necessary on the lighter lands in the drier counties of England for obtaining crops of wheat, when the land has been allowed to remain for a longer period than one year in grass. Thus the Norfolk farmer is in a great measure shut up to the necessity of having two white crops in four years, and of expending large sums in the purchase of cake for feeding and of artificial manures.

The climate of Norfolk is not so well suited to the growth of turnips as the west of England, Ireland, or Scotland, but the turnip is a more prominent crop in Norfolk than it is in any of those places. Turnips are an expensive crop, and in the feeding of stock, do not directly pay the farmer for raising them. They, however, are a necessary part of the system in Norfolk, even when sown to so great an extent as one-fourth of the arable land.

In the Norfolk rotation, one-half of the land is in equal parts of barley and wheat, which are both high-priced grains. The raising of these two grains can better afford a loss to be made upon the turnip-crop, than if oats had taken the place of either the one or the other. In the moister climates, which only admit of inferior grains being sown, the turnip, though easily raised, never occupies a fourth of the extent of the farm, as is the case in Norfolk. The raising of the crop for feeding cattle or sheep does not pay of itself; and hence, on farms where oats are the principal grain raised, pasturing the arable land for more than one year is the course always followed.

It is highly important to draw the distinction between the cattle crops that pay the farmer and those that do not. Mr Mechi and Mr Caird have expressed very different opinions on the economy of feeding—opinions, indeed, quite antagonistic. The former maintains that live-stock do not pay at all, while the latter affirms that they are the most lucrative sources of profit to British farmers. The truth, however, is, that such crops as turnips, which are raised at a great expenditure of labour and manure, do not yield, on the average, a direct return equivalent to the expense of raising them. On the other hand, grasses and clovers, which grow without cultivation and manure, yield a return in the feeding of stock equivalent to the landlord's rent and tenant's profits. Looking at the expenses connected with the two crops, we have always thought that the ordinary rates which a grazier will give for a field of turnips and a field of grass are sufficient to guide us on this question.

A large breadth of turnips can only be economically raised as part of a rotation, where, as is the case in Norfolk, barley and wheat are raised to a great extent. It is for this reason that agricultural tourists, from the days of Arthur Young, have remarked with surprise, *that this crop is never raised so extensively in those districts which have a climate particularly well suited to it, as it is in Norfolk.*

Turnips, being an ameliorating and less profitable crop, are never so extensively cultivated on rich land as upon poor. On rich land, potatoes or beans, yielding more profit, are substituted; so that even where the soil is well adapted for turnips, this crop, on high-priced land, does not usually exceed one-sixth or one-seventh of the arable land of the farm.

It would be out of place, in this short article on agriculture, to enter particularly upon this interesting subject; and we shall only contrast the Scotch and Welsh systems of rotation with the Norfolk.

In moist climates, the general system is to rely to a great extent upon grasses for renovating the fertility of the land, when it has been exhausted by crops of cereals. Though cereals, as is well known, are inferior in quality in moist climates, yet they are there raised at less expenditure for manure. This circumstance, and the less amount of labour expended in cultivation, form a certain compensation, so that arable land is fully as valuable when devoted to cereals in the west side of the island as on the east. These principles are well brought out in Mr Read's essay on the Farming of South Wales, contained in the *Journal of the Royal Agricultural Society*. In answering the question, 'How far is it desirable to adopt the four-course shift in the moist climate of the west of England?' he writes:

'The only artificial manure that has been extensively tried is guano, which has been found to answer admirably for corns, root-crops, and grass; indeed, the effects are sometimes double those which are produced by the same manure in the east of England. The great activity and increased luxuriance which are imparted to all crops by the application of good fertilisers, are conspicuous to any one who has seen the small returns produced by heavy dressings given to the gravels of Norfolk. The Welsh farmer, therefore, should adapt his system of improvements to his own soil and climate, and not to that of Norfolk, or any other totally different portion of the kingdom. It is always considered abominable farming to take two white straw-crops in succession; still, with moderately high farming, on good soils in this country, that abomination may be successfully practised. Experience has proved that, on the better lands, barley, after a drawn crop of turnips, will frequently lodge. Although the following course cannot be defended on the principles upon which a rotation of crops is founded, yet it is one best suited to the good land of this district: 1, turnips; 2, wheat; 3, clover; 4, wheat; 5, barley.'

In Scotland, the necessity of having a large extent of land under turnips was not felt up to

1813, the date of Sir John Sinclair's Appendix to the General Report. Before the opening up of the London market by steam-navigation, the feeding of cattle was not much followed. In 1813, the six-course of rotation was most generally adopted on the best farms in the Lothians—that is, 1, fallow; 2, wheat; 3, clover; 4, oats; 5, beans; 6, wheat. On the lighter and fertile soils, the five-course was not uncommon: 1, fallow; 2, wheat; 3, barley; 4, grass, one or two years; 5, oats.

The modern improvements in these systems, owing to the drainage of the soil, has been the substitution of turnips for bare fallow, followed largely by barley instead of wheat. Since the abolition of the corn-laws, barley has greatly increased in price, while the value of wheat has fallen, so the difference in value betwixt these two crops is not so great as formerly. Potatoes of late years now occupy three-fourths of the land on which beans were formerly grown.

The Berwickshire four-course shift is not so productive of wheat or barley as the Norfolk. Even were so large a proportion of the arable land in turnips as a fourth, it is difficult to obtain a fourth of the land in wheat without curtailing the extent of barley. Wheat not generally succeeding well in Scotland after grass-crop, the rotation is often: 1, turnips; 2, wheat or barley; 3, grass, one or two years; 4, oats.

It is often asserted that the climate of Scotland is unsuited to the growth of wheat, and that the inferior grains, oats and barley, can be raised with greater advantage. The practice of farmers who cultivate the best soils does not countenance such an idea.

Everything indicates that, although it may be profitable to cultivate spring crops under an inferior system, improvements in Scottish agriculture, where the climate is suitable, must evidently take the direction of increasing the extent of the two most valuable cereals, barley and wheat. But the other aspects of this question will be best treated in the paper on CATTLE AND DAIRY HUSBANDRY.

FARM-BUILDINGS.

Each farm must possess a residence for the farmer, cottages for the servants, and buildings for the stock and crop. The *farm-house* should be commodious and plain, with an extent of accommodation about equal to that which those have who are engaged in commercial pursuits in town, employing the same amount of capital. The cottages for the servants should be roomy, and internal convenience more studied than outward ornament. A kitchen and two bedrooms are essential for common decency.

Proper offices are necessary for the economical disposing of the produce of the farm. The corn crops are usually thrashed there, and a large portion of the green crops is consumed by stock, which must be well provided with shelter from the cold. When few turnips were raised, and few cattle fed, large open courts were best suited for converting the straw into manure. Now, however, in many cases, the excrements of the stock are sufficient for wetting all the straw, and hence has arisen the practice of box-feeding. In this case, the solid and liquid excrements are carted out along with the straw, which acts the part of a sponge. This is, no doubt, an excellent way of manufacturing home-made manure. It takes a considerable quantity of straw, however; and as more green crops are raised and consumed on the farm, sufficient straw cannot be got to absorb all the liquid; hence a saving of the straw is effected by stall-feeding, when the excess of liquid must be collected into tanks, and otherwise disposed of. When it is remembered that ammonia cannot be purchased in the market at the present time under £100 per ton, the utility of husbanding this material when it is freed as the excrements of the stock decompose, must be self-evident. If the solid excrements are kept in a compressed state, no fermentation takes place; and if the manure is of good quality, it should be applied to the fields at once. Liquid manures should be carted out or distributed by pipes, when the plants are in a growing state, otherwise part of it will be washed out of the soil. Covered farm-yards are rapidly extending over the country. It is the cheapest and best way of erecting farm-offices. Our frontispiece represents a bird's-eye view of a 'Model Farm-steading,' designed by Mr J. Lockhart Morton, for a farm of 500 acres, and a model of which was commended by the judges of the Berwick cattle-show in 1854. The steading is on the covered principle, all the various departments being under one roof.

Ventilation.—'Without good ventilation,' to use Mr Morton's own words, 'a covered homestead must be a nuisance. All the apartments are so arranged that, unless fresh air circulate through them, and they are kept perfectly clean, there must constantly be unwholesome effluvia in the interior—the foulness of one apartment being communicated to another. The system of ventilating this model farmstead is certain to give most satisfactory results, if only ordinary care be taken to keep the different houses as clean as they ought to be.' His arrangements are briefly as follows:

Under each feeding-passage is built a circular ventiduct or air-shaft, thirty inches in diameter; in connection with these there are feeding-mouths with gratings on the outside of the building; inside, there are numerous finely perforated gratings; by sliding-valves, wrought by a cord and pulley, the supply of air is regulated. Besides these, there are gratings every ten or twelve feet along the exterior walls, perforated so as to admit near the floor a considerable quantity of air. The roof, too, is provided with ventilators with vertical spars, and openings are left here and there in the sarking to act as induction and eduction tubes. The numerous perforated apertures throughout the building will admit twice the quantity of air required for the respiration of the animals, and are so under command that they will neither admit flies in summer, nor too large a supply of cold air in winter. A covered steading, somewhat similar in construction to Mr Morton's, has been erected at Glen, in Peeblesshire, where the ventilation of the inclosed cattle-courts, &c. is admirable.

We would only remark, that to carry out this principle of ventilation is somewhat expensive. A cheap and yet efficient system of ventilation for cattle, is to cover the yards with pan-tiles without plaster or lath. Those who wish to see farm-offices economically erected, at the same time

combined with the most perfect ventilation, we would recommend to visit some that were built not long ago on the property of Lord Kinnaird, Rossie Priory, Perthshire. As a general rule, farm-steadings are erected at too great an expense.

Choice of a Farm.

Farms, as to size, are usually divided into small farms under 100 acres; moderate-sized farms from 100 to 250 acres; and large farms of from 250 to 1000 acres and upwards, of land fit for cultivation. Each of these sizes is adapted to particular districts and other circumstances—especially to the degree of fertility and the amount of capital employed. It is a common but injurious mistake to suppose that the more land a farmer holds, the greater must be his profits. The profit does not arise from the land itself, but from the manner of using it; the best soil may be made unproductive by bad management, and the worst may be rendered profitable by an opposite course.

In Ayrshire and Wigtonshire, where dairy husbandry is well understood, and has arrived at greater perfection than in any other part of Scotland, the farms are of moderate size, being in general from 60 to 160 English acres. A farm of about 127 acres is reckoned a good size, and on this from ten to twelve cows are kept. On many farms from 50 to 100 cows and upwards are kept; but in these cases the cows are let at a rent per annum, the farmer supplying the cows and food, while the manual labour and the marketing of the produce is undertaken by the contractor, known as the *bower*. 'Where the soil,' says Sir John Sinclair, 'is of a light description, a larger extent is necessary, as in such soils sheep and cattle are frequently fed in large numbers; and a farm of this description, of from 600 to 1000 Scotch acres, or 762 to 1270 English, is not considered too large. Where farms are almost entirely employed in pasturage, or in the breeding of sheep or cattle, as is usually the case in hilly districts, there can be no precise limits to their extent; some in the Highlands of Scotland, devoted to sheep-pasture, reach 25,000 English acres.'

The selection of a farm requires the whole ability and experience of the farmer. He must attend to all the advantages and disadvantages regarding it, so that he may fully make up his mind as to the amount of rent he considers it worth, taking care neither to be too cautious nor too rash. There is one common but very erroneous rule which guides the choice of a farm—namely, the success of the outgoing tenant. If he has made money in it, or is leaving it for a larger one, numbers will flock after it, and offer a high rent, without even inspecting it. But if the tenant be unsuccessful, all his misfortunes are attributed to the badness of the land, not to his own mismanagement; and few will be found willing to take the farm even at a reduced rent. These notions are very absurd; for the management of various farmers is so essentially different, that success or misfortune may be said to depend more on that than on either rent or quality of land.

Leases and Rents.

A farm is seldom conducted properly for the legitimate advantage of either landlord or tenant, except a lease of considerable duration be granted; for if the tenant be at all times liable to be dispossessed at the mere will of the proprietor, he can have no interest in improving the land, and therefore cannot afford to pay a sum suitable to the actual capabilities of the soil. According to the modern practice of agriculture, the profits of a farm are frequently prospective; a number of years must sometimes elapse before the ground repays the farmer for his sunk capital, and his trouble in effecting improvements. The duration of a lease consequently depends on the nature and condition of the soil, as well as some other minor circumstances. It is well known that a long lease is a much greater stimulus to spirited farming than a low rent. At the commencement of every lease, great exertions are made to effect improvements, and to add to the manurial condition of the soil. The continuation of these improvements depends much on the ability, energy, and education of the tenant, while many fear having to pay additional rent, on account of improvements made by their own skill and capital. It appears from all experience in Scotland, that leases shorter than nineteen or twenty-one years decidedly check the outlay of capital by farmers, in what may be considered permanent improvements. If tenants had a legal claim for all capital expended on a farm which, in the opinion of skilled men, enhanced its value to the succeeding tenant, a greatly increased produce over the whole kingdom would speedily take place. The immense expenditure on manures and feeding-stuffs now annually made, renders a revision of the laws betwixt landlord and tenant a necessity, in the interests of the general public.

The connection between landlord and tenant is that of a disjunctive copartnery. The tenant trades upon a certain sunk capital of the landlord. The question, then, as to what is to be paid in the form of rent, is determined by the value of this capital, and what return it will produce annually on an average of years. From this return the tenant is supposed to draw one share, while the other is handed to the proprietor of the ground. With respect to grazing-farms, they are let on the principle of how much stock they can regularly maintain; and not being liable to the same expenses for management, both landlord and tenant receive larger shares out of the gross product. In some instances, proprietors, from negligence or a wish to retain an undue power over their tenants, delay the renewal of the farmer's lease till the period is almost expired. This is highly injurious to both parties; as, while uncertain if he is to continue on the land, the tenant will naturally be slack in his exertions to improve it, or even to maintain it in a fair condition. This evil might be easily avoided, by the proprietor renewing the lease of his tenant a few years before the expiration of the time. Should the land have materially increased in value during the lease about to expire, it will be found most advantageous for the landlord to nominate a judicious valuator, and to offer the farm at the declared rental to the existing tenant, without bringing it to public competition.

In drawing up leases, it is customary to introduce clauses restricting the tenant to certain rotations of crops, manuring, &c. applicable to the few years which precede the termination of the contract. These clauses, and also others respecting

the keeping of fences and roads in repair, are sufficient in all ordinary cases. Some landlords may be desirous of prescribing the exact mode of management of their farms; but this has a discouraging and injurious effect, and should therefore be avoided, except in what may be called improving leases, or engagements to improve the land in a certain manner. With regard to the form of a lease, it should commence, says Sir John Sinclair, 'with the necessary preamble, stating the parties contracting, the situation of the property to be leased, the extent of the farm—a plan of which ought to be subscribed by the contracting parties—the duration of the lease, and the time of entry: it is then proper to enumerate, 1st, The powers and privileges reserved to the landlord; 2d, The obligations incumbent on the tenant; and 3d, The stipulations obligatory upon both. Leases thus drawn up would not be liable to much uncertainty or dispute; and lest any should occur, it is expedient that a mutual obligation for settling by arbiters should be inserted.'

In modern farming, rent is altogether payable in money, or partly in money and partly in grain. The system of grain-rents was at one time highly popular with tenants in Scotland, as it equalised in a great measure the risk of bad seasons and low prices between farmer and landlord — not requiring from the former a fixed amount of rental from an uncertain and fluctuating source. Thus, for example, a farm at the nominal rental of £500 a year would be let for £250 or £300 in money, the remainder being payable in so many quarters of wheat, barley, and oats, at the fiars prices * of the county. However, tillage farmers do not now depend on the returns from grain-crops, at least to the extent they formerly did, for payment of their rents. From thorough draining, the use of artificial manures and feeding-stuffs, and the advantage of railway communication to all parts of the kingdom, the growth of potatoes and feeding of stock have enormously increased, and quite changed the character of farming within the last thirty years. As a rule, landlords prefer knowing their exact income, and farmers what they have to pay, so grain-rents are being gradually superseded by a fixed money payment. It should not be forgotten that grain-rents were first introduced into Scotland by John, Earl of Hopetoun, in 1822—and whose example was speedily followed by most of the large landed proprietors—an event which in that year reduced rents one half, and thus saved the tenantry from total ruin.

The periods of the year at which tenants remove from and enter farms are very various. In many parts of England, Michaelmas, or 29th of September, is the period for both grazing and arable farms, that being the most suitable on account of the number of great stock-fairs held at that time, and other circumstances. In Scotland, Martinmas, or 11th of November, is the usual period; though in East Lothian and the Border counties, Whitsunday is the more frequent term of entry. It is considered to be a most advantageous rule, that in all cases the removal of an outgoing tenant should be entire, not partial, as bit-by-bit removals too often lead to disputes between the retiring and entering individuals.

* Fiars prices in Scotland are the average prices for each county, as fixed by the sheriff with a jury, upon the evidence of the principal buyers of grain within the district. The average is usually struck about the beginning of March for the crop of the preceding year.

Arrangement and Management.

With respect to the arrangement and management of a farm, we cannot do better than extract the excellent digest of rules from the *Code of Agriculture:*

'1. The farmer ought to rise early, and see that others do so. In the winter-season, breakfast should be taken by candle-light, for by this means an hour is gained, which many farmers indolently lose, though six hours so lost are nearly equal to the working-part of a winter-day. This is a material object where a number of servants are employed. It is also particularly necessary for farmers to insist on the punctual performance of their orders.

'2. The whole farm should be regularly inspected, and not only every field examined, but every beast seen at least once a day, either by the occupier himself or by some intelligent servant.

'3. In a considerable farm, it is of the utmost consequence to have servants specially appropriated for each of the most important departments of labour; for there is often a great loss of time where persons are frequently changing their employments.

'4. To arrange the operation of ploughing, according to the soils cultivated, is an object of essential importance. On many farms there are fields which are soon rendered unfit to be ploughed, either by much rain or severe drought. In such cases, the prudent farmer, before the wet season commences, should plough such land as is in the greatest danger of being injured by too much wet; and before the dry period of the year sets in, he should till such land as is in the greatest danger of being rendered unfit for ploughing by too much drought. The season between seed-time and winter may be well occupied in ploughing heavy soils, intended to be laid down with beans, oats, barley, and other spring-crops, by means of the scarifier. On farms where these rules are attended to, there is always some land in a proper condition to be ploughed.

'5. Every means should be thought of to diminish labour, or to increase its power. For instance, by proper arrangement, five horses may perform as much labour as six, according to the usual mode of employing them. One horse may be employed in carting turnips during winter, or in other necessary farm-work at other seasons, without the necessity of reducing the number of ploughs. When driving dung from the farm-yard, three carts may be used—one always filling in the yard, another going to the field, and a third returning. By extending the same management to other farm-operations, a considerable saving of labour may be effected.'

To this digest it may be added, that the farmer should habituate himself to keep regular accounts of his affairs, which may be done by means of a cash-book for all outlays and receipts as they take place; a labour-book, in which to mark the commencement and time of work of every individual employed; a journal for entering daily transactions and memorandums; and a ledger, in which a special debtor-and-creditor account is kept of

every department, as well as a general account of the whole concern.

WASTE LANDS.

According to the agricultural statistics of the Board of Trade, it appears that out of the 77,500,000 acres in the United Kingdom, only 46,000,000 are in cultivated arable and pasture land, the remaining 31,500,000 being thus distributed:

	Acres.
Woods and plantations	2,000,000
Sheep-walk (Scotland)	7,000,000
Uninclosed pasture (Ireland)	8,000,000
Mountain, peat, and flat red bog (Ireland)	3,000,000
Other waste—say	11,500,000

Much of this large proportion of our territory is either situated at such an altitude, or else so naturally barren, as to be hopelessly beyond the reach of improvement; but estimating from Mr Couling's valuation in the year 1827, and the amount of land inclosed since that time, we have now about 16,000,000 acres capable of being added to the arable and pasture land of the kingdom.

Considerable misapprehension exists as to the character and capabilities of these cultivable waste lands, and we have no reliable authority furnishing us with exact information; however, there is sufficient evidence to shew that they generally consist of the naturally poorest or most unfavourably situated ground, or such as is least remunerative to the husbandman, owing to the heavy outlay required for its reclamation.

The Inclosure Commissioners, in their Twenty-seventh Annual Report, dated January 31, 1872, say: 'The extent of waste land held in "common" in 1844 was estimated at 8,000,000 acres, and that estimate was based on a return (taken partly from every county in England and Wales) of the actual amount of "common" found on an area which embraced one-fifth of the whole country. It may therefore be assumed to give a fair representation of the extent of "common land" at that time.

'In addition to the "common land" there is also a considerable extent of "commonable land," that is, land held in severalty for a portion of the year, upon which, after the summer crops are removed, certain rights of pasturage are exercised in common during the remainder of the year. This was supposed to comprise 2,000,000 acres, but there is no certain basis for this estimate. It is to be observed that these "commonable lands" are subject to tithe rent-charge, and are also liable for land tax, and to rates for parochial and local purposes.

'The estimate of 1844 of "common" and "commonable" land together, at somewhat over 9,000,000 acres, may, we think, be accepted as fairly accurate. In the twenty-five years since the passing of the General Inclosure Act, 670,000 acres of these lands have been and are in course of being inclosed, an extent equal to an average English county. This leaves fully 8,000,000 acres still to be dealt with, which is more than one-fifth of the entire acreage of England and Wales. Of this vast extent of country there is reason to believe that upwards of 3,000,000 acres will be found in the lowland counties of England, and the remainder in the mountainous and moorland counties, and in Wales. A large proportion of the "commonable lands," which are situated chiefly in the lowland counties, is undoubtedly susceptible of more profitable use and cultivation after inclosure. In addition to the "commonable land" (which at present is more or less under cultivation), we think it may be assumed as a very moderate estimate that, out of the "commons," one million acres might still be added to the productive area of agricultural land in England. To accomplish this, at the rate of progress hitherto made with inclosures, many years must necessarily elapse. Even when that is completed there would remain about one-sixth of the area of the entire country still open, and subject to rights of "common," an extent so great as must shew how erroneous have been the apprehensions expressed of the speedy inclosure of every common in England.

'In estimating the value to be attached to these figures, it will be borne in mind that they apply to a country of limited extent, where mining and manufacturing industry, railway extension, and urban population are constantly pressing upon the narrow limits of the cultivated land. The addition of one million acres would be sensibly felt; it is more than has been won from the sea in three centuries and a half by the laborious industry of the Dutch, and would be nearly equivalent to one-tenth of all the land at present under crops in England, exclusive of grass. This would be an outlet for labour and enlargement of cultivable country exactly the same as an addition of an equal extent of territory. Nor should it be forgotten that, when inclosed and cultivated, these lands would become a source of further revenue for all purposes of imperial as well as local taxation, and, being held in severalty, would add to the quantity of land capable of being brought into the market for sale and purchase.'

From the great decrease of inclosures during the present century, in spite of the vast and rapidly accelerating increase of population and demand for food, it is plain that but little ground yet remains waste which it would be worth while to cultivate, under our present system of tenancy and our present order of agriculture. The notion that there exist wide-spread tracts of good land, unprofitably waiting till their owners permit them to be tilled, is not correct; there are but few plots capable of ordinary culture which are not already brought under the plough, or appropriated to the pasturage of cattle. British agriculture has arrived at that point of its history in which the problem is, how to increase the yield from each acre, rather than where to extend the area operated upon. Still, so long as the system under which land is occupied continues to trammel enterprise and improvement, and so long as science and practical skill are so partially diffused among farmers, the waste lands will be resorted to by bold proprietors and venturesome tenants; and that instinctive preference felt by the great majority of men for agricultural before all other pursuits, will not fail to lead strong-armed labourers and town-wearied mechanics to push stone-walled inclosures up the steep sides of moors and fells, to creep with gardens and green crops up the sandy heaths, to tap dropsical mosses, and bale out the tide from fat marshes.

The question as to the propriety of reclaiming a really improvable waste is, in any particular case, to be satisfactorily answered by ascertaining at

what expense, in relation to the probable profit, the process may be performed. A barren rocky desert may be rendered productive by covering it with soil and manures brought from a distance of miles aided by years of skilful tillage; but will the returns in produce be an equivalent for the excessive outlay?

We will now proceed to describe the nature of the various waste lands, the best means to be adopted in reclaiming them, and the results which may be expected to reward the enterprising improver.

MOORLANDS, HEATHS, DOWNS, AND HILLY WASTES.

Our principal English *moors*, as distinguished from the fells and actual mountains, are in the counties of Northumberland, Durham, Cumberland, Lancaster, York, Stafford, Chester, Derby, Devon, Cornwall, Somerset, &c.

The Yorkshire moors are the most extensive and important in England. The eastern portion, principally in the North Riding, rise about 1000 feet above the sea. The surface of some of the hills is entirely covered with large freestones; and in other places mosses, sometimes very large; the prevailing soil being peat-earth, which is generally covered with heath. On that portion called Hambleton Hills, the soil is much better, being good loam on a limestone rock. The climate is dry, but cold and backward; however, portions of these lofty and exposed regions have been brought into tillage; and sheep are being fed on what used to be the haunt of the wild mouse and the mole, and luxuriant oats wave before the wind that used to whistle through the whins and the heather.

The western moorlands, almost equally divided between the North and West Ridings, are of very great extent, but not generally so sterile as the eastern. Many of the hills are covered with fine sweet grass; while in other places there are large tracts of heather mingled with grass, bent, or rushes. On these waste lands of the millstone-grit formation, the productiveness of many inclosures shews what a large extent yet unreclaimed is capable of. There are many instances of this high ground growing nothing but heather, and not realising more than about 1s. 6d. per acre, shooting included; whilst immediately adjoining, on the same level, are cultivated plots letting for 20s. 25s. and up to 30s. per acre, and producing excellent crops.

The Derbyshire Peak is very wild and barren, not so much from its altitude as from the steep, rugged, and nearly soilless sides and crags of the limestone and the millstone grit, and from its bogs and moorlands covered with heath and boulder-stones of every size; while the streams carry down the waste of crumbling grits and shales in their peaty, brackish waters, to enrich the meadows and vales below. The soils on the grit are chiefly of a sandy kind; the great difficulty in cultivating being the first clearance or removal of the rocks and blocks everywhere scattered over the surface. Vast tracts have been cleared and taken in.

Cornwall contains about 200,000 acres of waste, the greater part being held in common by surrounding farmers. To shew what skill, enterprise, and capital will do on some of the most exposed parts of the granite wastes, Mr Karkeek says, in the *Royal Agricultural Society's Journal:* 'Let the reader imagine a piece of waste strewed over with granite blocks, some of immense size, with heath and furze shooting up in the interstices, at an elevation of 600 feet above the sea-level; and notwithstanding these natural obstacles, I witnessed a short time since, on an estate of only 150 acres—not many years since reclaimed from the Sancreed wastes—130 head of cattle, Devons and shorthorns, 100 pigs, and 35 horses and colts. The average produce is from 45 to 60 bushels of oats, from 18 to 21 of wheat—not much grown—300 bushels of potatoes, and from 18 to 25 tons of turnips. It frequently happens that the first crop of potatoes raised on this reclaimed land will more than repay the expenses.'

In North Wales there exist extensive tracts of waste upon the mountain-sides capable of cultivation. On the Hiraethog range, the luxuriant growth of the heath, fern, and foxglove in many places, is a clear indication of the riches that are in store for the first adventurer who may attempt to break up the almost desert waste; and many patches of deep hazel loam are seen, which have been lately reclaimed from the wild state, now covered with oats and grass of the best description. There are wide-spread tracts of land in Merioneth and Montgomery shires, which, by paring and burning, draining and liming, would produce excellent crops of turnips and rape—enabling the farmer to maintain as large a flock of sheep in winter as in summer, instead of being compelled to draft them off to lowland graziers, as at present.

Devonshire comprises about 455,000 acres of waste land, much of which may be rendered productive. Dartmoor—no less than 250,000 acres uncultivated—has principally a peaty soil, which during the summer months is dry and firm; in other parts, as in Dartmoor Forest (80,000 acres), there exists a perfect swamp even in summer. The mean elevation of the district is nearly 1800 feet above the level of the sea; the climate cold throughout the greater part of the year, and materially impeding vegetation. Undoubtedly, the main cause of this unfavourable climate is the want of drainage; and it is nearly useless for private individuals to attempt isolated inclosures until all the district has been drained by a simultaneous and united undertaking.

The inclosure of Exmoor Forest, in Somersetshire—20,000 acres, at an altitude of 1000 to 1200 feet—is one of the most striking examples of the improvement of waste land. The surface is in the form of an undulating table-land, furrowed by deep stream-valleys, and covered over almost its whole extent with a moist pasture. There is considerable depth of soil on the boggy portions, which, when drained and limed, makes good land. Rain and mists, and Atlantic gales, are the principal opponents of the cultivator; but plantations and good hedges are rising to afford the requisite shelter. The best fence for this purpose consists of a bank of earth, supported on both sides by stone-walling, five or six feet high, and six feet thick at bottom; and on the top of this, beech-trees are planted, and found to grow well. Mr Knight, the proprietor, has erected a large number of farmhouses and cottages, and constructed nearly 30 miles of road, and 150 miles of

wall or bank-fencing; and a large portion having been pared, and burned, and limed, is now growing roots and grass, and indeed oats also with great success. One of the most remarkable features of the Exmoor improvements consists in the control of the water. Instead of the drenching rains being suffered to wash away fine particles of soil, manure, lime, or ash down the hill-sides, the water is caught in carrier-canals and reservoirs, conducted along the sides of the declivities, and made to trickle down over water-meadows, or, with soil in suspension, allowed to rush over the surface where wanted, or else employed to turn mill-wheels and machinery at the farm-steads.

This leads us to notice very briefly the subject of *Irrigation.*—The object to be obtained is to flood the land at pleasure in such a manner as to maintain an incessant shallow flow or trickling amongst the blades of herbage. To give the surface the requisite inclination in every part, to design and lay out the *carriers* which bring the water, and the intervening drains which convey away the spent floods, according to the levels of the land, and have the water under perfect command, requires very considerable knowledge and judgment. The water is to run in the months of October, November, December, and January, from fifteen to twenty days at a time, with intervals of five or six days for the ground to dry and air. The question as to what water is suited or not for the purpose, is also one of some difficulty.

The Duke of Portland's water-meadows at Clipstone Park, in Nottinghamshire, are the most famous in England: many miles of a swampy valley, thick set with hassocks and rushes, the favourite haunt of wild ducks and snipes; hill-sides covered with gorse and heather; and a rabbit-warren, over which a few poor sheep wandered, having been changed into a succession of the richest meadows, producing a marvellous quantity of green cuttings and pasturage.

The Scottish moors are too frequent and extensive to be particularised. The moor of Rannoch, in the neighbourhood of Ben Nevis, includes a vast tract of rocks, lakes, and morasses, elevated about 1000 feet above the level of the sea, and is one of the most dreary, wild, and worthless districts imaginable. It is not inhabited, and seldom even visited. There is a somewhat similar district on the west coast of Cromarty and Sutherland; though without any great hills, and not very elevated, it is extremely rugged, bleak, and miserable. The soil of most of the Scotch moors, as well as of many of the mountains, is peat. On the granite formation, the soil is thin and poor, and situated in a cold bleak climate. It is of no agricultural value, so far as the production of corn and roots is concerned, and is covered with heather and coarse grass. On the whinstone or trap hills, the soil is of a very light character, and was first improved by the introduction of bone-manure, so that now oats and turnips are grown nearly 1000 feet above the level of the sea. In the Highlands, prodigious improvements have been made by clearing moors of stones, burning heather, extensive planting, draining mosses by open ditches, collecting and distributing the water along the hills by means of artificial canals; and improving the natural grass growing upon a thin soil, by draining and by grazing with sheep.

The most extensive of the *heaths and sands* of England are those of Surrey, Dorset, Hants, and some other counties, as Norfolk and Suffolk. The heaths of Surrey, particularly that of Bagshot, consist of a sterile and apparently unimprovable sand, for the most part level, but elevated between 400 and 500 feet above the sea. Only a few patches of good loam are to be found; so that the district will probably remain worthless, in an agricultural point of view, and its products be confined to a growth of heath, gorse, fern, and to a few plantations of larch and Scotch fir. 'On Bradley Common,' says Mr Evershed (*Royal Agricultural Society's Journal*), 'an extent of more than 100 acres is being reclaimed at an expense of £7 or £8 per acre; but it appears doubtful if the larch and fir which have been planted will thrive. The process of breaking up the ground consists in paring, burning the heath, and trenching, by spade and pick, to the depth of twenty inches, or more, according to circumstances. This depth is generally sufficient to break through the 'iron crust,' which is invariably found below the surface of the sand, and which, being impervious to water, is the cause of the heath's being frequently wet and boggy.'

The heaths in Dorsetshire and Hampshire are very extensive. In the former county, plots of twenty or thirty acres are taken at nominal rents by small farmers for reclamation. Mr Ruegg (*Royal Agricultural Journal*), says: 'The land is broken up with large mattocks, at a cost of £2 per acre; the surface is either burnt or worked about until the turf decomposes. The next process, chalking, is very expensive; as they go from three to five miles for the chalk, and though it costs at the pit only 6d. a ton, its cost on the land is £3 an acre. It might pay to sink a shaft, as they do in Hampshire. The general dressing is twenty tons an acre; but on sandy soil this is thought too much. It is worked down with Crosskill's clod-crusher, and scarified, and sown with turnips or rape. It is well dunged, and two or three good crops are taken from it, but at a heavy cost. The green crop is eaten off, and very large crops of oats obtained—as many as sixty or seventy bushels per acre.'

The chalk *Downs* of our southern counties remain to be noticed—including Salisbury Plain, in Wiltshire—an elevated table-land, with a thin, light, and flinty soil, covered by a fine greensward. In Dorsetshire, a very great extent is being broken up every year; and land, but lately the habitation of foxes and rabbits, producing furze, fern, and a scanty portion of sheep-feed, with a return of only 2s. 6d. an acre, is now yielding £1. Breast-ploughing and burning the turf is the first operation; and after a crop of rape, wheat, and clover has been taken, the land receives an application of chalk.

Although it might not pay the farmer to break up very lofty, steep downs, having scarcely any soil, still thousands of acres in Sussex, Wilts, and other counties, now depastured by flocks of sheep folded on arable land at night, and extensive tracts, producing little but heath and furze, might be brought into profitable tillage, and made to yield in sainfoin, clover, and other artificial grasses, an amount of food immensely greater than that afforded by the natural herbage. Many trials have been commenced, and afterwards

abandoned, by those who neglected the principle that the soil has to be made, and enriched by manures and green crops fed off with sheep, instead of immediately taxed with corn-cropping; whereas, there are innumerable instances to shew that light chalk-lands, as well as other wastes, will prove worth reclaiming, if only persevered with: tillage and the application of mineral and animal manures, for a course of years, having the effect of creating a good soil where scarcely any existed before.

The basis of improvement in light, silicious soils is the application of chalk, marl, or clay; this admixture giving greater solidity and retentiveness for moisture, a power to arrest and retain organic riches from the atmosphere, while supplying many mineral substances required in the constitution of a fertile soil.

Marling and Chalking.—Marl is a term applied in different localities to a variety of earths, generally consisting of a mixture of clay, sand, and lime, but also including such substances as red or blue clay of an unctuous or pulverulent character. Marl-beds are found in hollows at the foot of hills, at the bottom of ancient lakes, below peat-mosses; particularly in districts where chalk-hills, limestone rocks, or spring-waters containing much lime in solution, abound. *Clay-marl*, used in Norfolk and Suffolk, is the *till* of the diluvial or drift deposits, consisting of blue and yellow clay containing lumps of chalk. A common dressing upon gravelly or sandy land is from forty to seventy cubic yards per acre. The cost of filling and spreading is about 3d. per yard; and of the cartage, according to the distance. *Shell-marl* is a kind found under bogs and mosses, and at the bottom of most dried-up lakes, and is evidently a calcareous earth, formed of decomposed testaceous fish.

Chalk is employed as a manure and mechanical solidifier of light soils, in every locality where it exists, and has been the chief agent in improving the thin, flinty loam of the Lincolnshire wolds. It is there excavated from pits or quarries, and carted upon the land at an expense of 5d. or 6d. per cubic yard. A dressing of 80 to 100 cubic yards is applied per acre; the chalk is weathered by exposure to a winter's frost, and then crumbled down by harrowing. On the Chiltern Hills of Buckinghamshire, pits or wells are sunk in the fields, about twenty feet deep, and the chalk drawn up in baskets by a wheel.

MOSS-LANDS, FENS, AND MARSHES.

Peat-mosses are supposed in some cases to have been occasioned by the destruction of ancient forests, either by the hatchet or from natural decay. In other cases, bogs have been formed by aquatic plants vegetating in hollows, holding water; mud accumulating round their roots and stalks, formed a semi-fluid mass, which increasing gradually, filled up the hollows, so that sphagnum and other mosses could grow. The peat which has been formed in this manner is therefore a compound of vegetable substance not entirely decomposed; commonly inclosing decayed trees, of pine, birch, hazel, or oak. The lowest layers of peat are commonly formed of aquatic plants; the next, of mosses; and the highest, of heath. The quality of the bog may be judged of from the plants which grow upon it: on ground completely saturated with water, various species of moss grow, to the total exclusion of other plants; but if the land should in any way become drier, reeds, rushes, and other plants spring up in the place of the moss; and all the moss tribe, the horsetail and the marsh trefoil, are fibrous, and difficult to decompose; while reeds, rushes, and sedge are comparatively easy of decomposition.

Morasses abound in all mountain and moorland districts, particularly in Scotland; while extensive tracts of flat mosses and peaty land are found in Lancashire, the fen-country of Cambridgeshire and Lincolnshire, and in Somersetshire. In Ireland, the mountain peat occupies 1,300,000 acres, and the flat or red bog 1,600,000 acres, including the extensive tract known as the Bog of Allen.

The following are examples of successful undertakings upon various descriptions both of the flat or red bog and the black or hill peat.

The reclamation of a large portion of Chatmoss, in Lancashire, was commenced by Mr Roscoe of Liverpool, and has been subsequently prosecuted with success. Drainage—the first step to improvement—was effected by cutting open parallel ditches 66 yards apart, 4 feet wide at the top, and sloping down to about 14 inches at the bottom, 3 feet 6 inches deep. In a wet floating mass like this moss, it was not possible to sink the ditch to the whole depth at once; and the first two spits being taken out, it was then left for time to consolidate the surface. The covered cross-drains, 10 yards apart, laid 3 feet deep, and running into the open ditches, were commenced; but in forming these, as well as the open drains, it was necessary to allow some time to elapse between the different operations, that the water might to some extent run off; the hollow drains being made by the top sod, dried by exposure to the air, being wedged into the open cut, and the peat thrown in again upon that to fill up. When the surface was partially dried, the heath and other plants growing upon it were set on fire, and burned off as closely as possible; and by ploughing and cross-ploughing, and cutting up the sods by a roller armed with knives, the tough and elastic character of the surface was destroyed. Both men and horses were obliged to work with pattens or flat pieces of wood attached to their feet. After this process, marl—found at the southern edge of the moss—was laid on the top, by means of a movable railway; the dressing being 100 cubic yards to the acre—equal to about one inch covering over the whole surface—and the average distance which the marl had to be removed, about two-thirds of a mile. Town-manure was brought by the Liverpool and Manchester Railway—a mixture of night-soil and ashes being preferable to anything else; and by growing a crop of potatoes in the first instance, the different particles of moss-earth and manure became so thoroughly blended together that the soil formed would produce anything, and wheat, clover, and oats followed each other in successful rotation. After-experience has shewn that turnips, oats, and potatoes are the best crops for such land; and an admixture of lime and salt answers better than the bulky marl for destroying the vegetable fibre, converting the moss into friable mould, and preparing it for a first crop of potatoes. On the extensive

mosses in the Fylde district of the same county, oats and potatoes, turnips, and even wheat, may be seen growing on the surface of bog perhaps thirty feet or more in depth; and, indeed, to cultivate a bog is a much less difficult task than to improve a moor, because the peat is only an excess of manure more readily destroyed than created. Main drains are first made conformably to the extent, configuration, and situation of the moss, to the levels of surrounding lands, and to the levels of the substratum on which the moss rests. Roads are formed by first cutting open drains on each side, and throwing the material into the centre of the intended roadway; and when this is tolerably dry, sand or gravel is laid on, several inches thick, and four yards wide. Open ditches are made, dividing the land into fields of about four acres each, and covered drains are laid at ten-yard intervals. These are wedge-drains, similar to those of Chat-moss, and are three feet deep. The whole expense of draining each field of four acres amounts to about £1, 6s. to which must be added a share of the outlay for the general main drain or canal, and for roads. Marl to the extent of 100 or 110 tons per acre is then applied by a portable railway, at a further expense of about £1, 14s. per acre. The value of the land thus reclaimed is often more than £1 per acre to rent, and is calculated to pay more than 10 per cent. on the outlay.

Some of the most unpromising bogs in Ireland have been converted into fertile soil, most commonly at an expense of about £15 per acre; though some have cost nearly double, and others, again, only £8 or £10—so much depending upon local circumstances, facilities for discharging the drain-water, and the distance of the marl, or other solidifying material, or the lime, which is so efficacious in altering their qualities. Black or mountain peat is generally situated favourably for drainage; and if marl, sand, or clay is not obtainable, and even lime cannot be procured, paring, and burning, and manuring will be found to produce, in time, a soil capable of bearing good crops; and this is the case even at very great altitudes, provided the reclaimer be content with rape or hardy turnips and grass-seeds for sheep-feeding, instead of trying to grow corn.

We have not space to describe the great drainages of our fens by embanking rivers, excavating straight instead of circuitous channels, lifting up the drain-waters from the low-lying lands by windmills and steam-engines, inclosing the muddy sands of estuaries and salt-marshes along the coasts from the sedimentary tides, and issuing the drain-water through sluices with self-acting valve-doors to keep out the sea. Tracts of open marsh deposited by the ocean still exist on the English coast, which it might be worth while to embank; in Ireland there are some very fine *slobs*, as they are there called; and in South Wales there are 11,000 acres of fen and marsh land, which, if drained, could be made into very excellent soil. We must allude, however, to a method of improving low flat land lying contiguous to tidal rivers or estuaries, and below the level of the tides at high-water—called

Warping.—The waters of the Ouse, Trent, and other tidal rivers converging to the Humber, hold in suspension a large amount of earthy sediment, locally termed *warp*, and by being conducted over the land, and allowed to deposit their slime, have covered some 20,000 acres of worthless peat-moor and weak sand with the richest possible soil. A sluice with opening doors is erected in the bank of the stream, a main-drain cut and embanked across the low lands to the ground intended to be warped; and the latter is surrounded with a well-sloped bank, sufficiently high to hold the water. The 'compartment' may be fifty acres or less—being so much as the farmer can conveniently spare at one time. The thick water enters the inclosure at the furthest side, and directly it expands into a quieter current, begins to let fall the deposit, passing slowly over the surface of the land on its way to the near side of the compartment, where a tunnel permits its escape back again into the drain at ebb-tide. The further side having received a sufficient coating, *inlets* are cut in the bank of the drain at a less-advanced position, until the water gradually silts up the entire inclosure. From one to three feet thickness of deposit is obtained in from one to two and a half years, according to circumstances; the expense, with large drains and other works included, ranging from £12 to £20 per acre; while on land adjoining the public warping-drains, it is much less than half that sum. When the new warp has become partially solidified, furrows are dug in it; and after being exposed to a winter's frost, seeds are sown, with oats to shelter them. These are grazed with sheep for two years, when, the excess of salt having drained out of the soil, beans, wheat, potatoes, and flax follow. This alluvial soil, rich in organic matter, is most prolific—worth £60 to £100 per acre—and commanding a rental of £2, 10s. or £3, or even much more.

The same kind of silt or warp is sometimes excavated from old river-channels, and by means of a movable railway, spread upon the boggy land to be improved.

In the Cambridgeshire and other fens, the peaty soil is improved by

Claying.—Pits are sunk in rows, say fourteen or fifteen yards apart; and on reaching the blue calcareous and greasy clay, at a depth of two to six or more feet, the workman casts out some two to four *draws*, throwing part on each side: the black soil removed in sinking the next adjoining pit is thrown into the last, to fill it up; and so on, across the field. The object in sinking pits is to prevent the sides from coming together, which would be the case if a long open trench were dug.

WOODS AND FORESTS.

Undoubtedly a very great extent of the royal forests and other wood-lands might be profitably grubbed up, and the land brought into cultivation. Wychwood, in Oxfordshire, about 4000 acres, was lately disafforested, having previously produced for the country only £100 clear annual return; though the soil is well adapted for tillage.

Exclusive of Windsor, the fourteen royal forests lying in various counties from Hants to Durham, cover at least 48,000 acres, capable of yielding a princely revenue, if properly planted, thinned, and generally managed; but having really produced, until very lately, little or nothing.

The New Forest is a tract of 66,000 acres, of which little more than a quarter were wood-land in

1849. Half the land consists of most excellent soil, the remainder being poor, barren, and worthless. Until very late years, there has been an annual deficiency, though the property ought to return at least £60,000 a year. In Nottinghamshire, Mr Evelyn Denison has grubbed up some extensive oak-woods growing on a red-clay soil, at a total expense of £17 per acre, and has found that in every case the timber, &c. upon the ground defrayed the entire expense, and left a surplus of £5 to £12 per acre—the increased annual value being about £1, 4s. per acre. Many thousand acres of our national forest-land might be similarly treated with the same advantage.

But besides bringing woods and forests into cultivation, immense quantities of land may be added to our present arable and pasture by the simple removal of useless fences, and curtailing the dimensions of those which are really requisite and necessary. Thus, around Exeter, the loss of land from the size and number of hedgerows amounts to no less than one acre out of ten; and in some districts of Norfolk, again, a like proportion of ground is thus wasted.

SPADE-HUSBANDRY.

Fig. 20.

The reclaiming and culture of small pieces of land by means of the spade and other instruments of manual labour, is usually spoken of under the name of spade-husbandry, but is also sometimes called cottage-farming or field-gardening—the operations of the culturist bearing an intimate resemblance to those applied in ordinary kinds of gardening.

It is very common for persons to argue against the practicability or advantage of settling the poor and hard-worked or out-of-work population on tracts of waste land—say in cottages with twenty acres, ten acres, or considerably less, to each family, assuming as the basis of their calculation that the cottager would make no more return from the same area of surface than the farmer who tries reclamation on a great scale. But innumerable facts contradict this assumption. Thus, the cultivation of the Bagshot sands has been attempted by many practical farmers, and afterwards abandoned; but it is a fact, that when the labourer puts his spade into this soil, he almost invariably succeeds in turning it into good potato-ground.

In his *Report on the Farming of Cornwall*, Mr Karkeek says: 'As a proof that a large part of the granite waste in the Land's End district would pay an almost immediate profit to the cultivator, I have only to state that a very considerable extent is now in progress of reclamation by cottagers, who obtain small plots of waste on leases of three lives, which they cultivate and build cottages on. When not very rocky or boggy, the land may be reclaimed at £5 to £6 per acre—fencing not included, which varies according to circumstances. On taking ground of this description into cultivation for the first time, the cottager does not attempt to grow wheat, but potatoes and oats; in the course of five or six years he introduces barley; and in ten or twelve years, wheat. . . . . An immense breadth of waste on the slate-formation has also been reclaimed by cottagers, chiefly miners. The soil is exceedingly thin, resting on red or yellow gritty clay and coarse slates, abounding in quartz fragments, and traversed by mineral lodes and elvan rocks in every direction. The late Earl of Falmouth and Lord de Dunstanville gave a great impetus towards the reclaiming of this coarse kind of land, by granting pieces from three to five acres to cottagers on leases of three lives, at a small rent of from 2s. 6d. to 5s. per acre, on condition of their building cottages on the holding. The parish value of these lots now averages from 10s. to 20s. per acre. The Earl of Falmouth has nearly 2000 tenements of this description, which have increased in value, since 1815, from 20 to 25 per cent.' It is supposed that no less than 6000 working-miners are possessed of cottages on land which they have reclaimed.

In one district of Lincolnshire, called the Isle of Axholme, the occupations are remarkably small, a great number of farms being under ten acres in extent, while single acres, half-acres, and even roods are general over large tracts of open-field land. The soil is a very rich sand-loam, managed chiefly by the spade, hoe, and fork, and yields abundant crops to the constant and complete tillage and cleaning which it receives. Potatoes, onions, and other garden produce form a large proportion of the cropping. Many of these small cultivators may be poor, especially those who, having been too eager for a plot of land, have borrowed too large a proportion of the necessary capital, and so fallen into the clutches of mortgagees; but as a general rule they are well off, earning an independent though frugal livelihood. Perhaps one-fourth of them are owners; and there is a constant emulation among the remaining occupiers to become proprietors by a thrifty industry, great prices being consequently given for small plots of land. On the rich soils of the Isle, where toil is the principal requisite in cultivation, an industrious family succeeds well in spade-husbandry; though on light lands, needing the trampling of the flock and the expenditure of heavy sums in artificial manuring, the man whose chief capital is in his sinews would be at every disadvantage; though even there it is found that, by taking an acre or so of garden-ground, the labourer is amply benefited.

And if these examples are insufficient to shew the desirableness of extending cottage-farming and spade-husbandry, we have only to refer to the prosperous cultivators of Belgium and Flanders on this system—distinguishing between the industrious habits and skilful husbandry, both in tillage, rotation of crops, and manuring, found in those countries, and the absence of these essentials of success in so many parts of Ireland, where small-farming does not preclude poverty.

We will now consider the general management and practical details of cottage-farming. The homestead is to consist of a cottage with several apartments, which, with every convenience of copper, oven, well, outhouse, &c. can be erected for £70 or £80; a cow-house, pigsty, and barn. The size of the farm is supposed to vary from three to six, eight, or more acres, according to the capital and amount of labour which the occupier possesses, and to be laid out in a suitable number of field-plots by proper fences. If the land be in a waste condition, it must be cleared and drained. If moss, dig open drains round it to draw off the water; scarify the surface with the spade, and burn the heaps of turf; scatter the ashes over the land, with any sandy material or lime which can be procured, and then delve all from one end to the other. If the land be choked with stones or roots, all these must be removed to the depth to which the after-digging will have to go. In the case of strong or clay land, under-drainage will be necessary; and this is easily effected in small plots of land, when there exists an adequate outfall, by burying broken stones, thorn-fagots, &c. in drains three or four feet deep, and moderately near together.

The tools required by the cottage-farmer are simple and inexpensive. They consist of two or three spades of different sizes; one or two of the light steel digging-forks now manufactured, which wonderfully reduce the labour of delving soil that has been stirred before; a pickaxe, hoes, rakes, scythe, reaping-hooks, hay-forks, flail, wheelbarrow, &c. according to means. A grinding-stone and a few carpenters' tools are also exceedingly useful. No horse or paid servant is kept, all the work being supposed to be done by the manual labour of the farmer and his family. The live-stock consists of a cow or cows, pigs, and poultry. To preserve manure without waste, a pit should be provided adjoining the cow-house, into which all the solid refuse and all that may be collected from the dwelling-house is to be removed. Liquid manure, and the drainings from the cow-house, &c. should be collected in a barrel sunk in the ground, and protected from the air. This is a most valuable liquid for throwing over the land to feed a young growing crop, especially for grass, &c. mown for the cow. A few shovelfuls of earth must be laid upon the solid manure whenever a layer of it is added to the quantity in the pit, so as to arrest the escape of any volatile and offensive gases during the process of partial fermentation. Rubbish of all kinds, withered leaves, stalks, clippings of branches, roots, &c. should be gathered into a heap, and occasionally moistened with urine from the cow-house, or mixed with a little lime, so as to rot down into valuable manure.

Whether it would be preferable to devote a cottage-farm to a mixture of green and grain crops, as in ordinary husbandry, or make it chiefly a dairy-farm, in which the raising of green crops for fodder is the main object, must depend on local circumstances. Generally speaking, it will be found advisable to make the maintenance of the cows the principal object, the crops consisting of rye, lucern, clover, Italian rye-grass, cabbage, tares, mangel-wurzel, turnips, wheat, and oats; the cows being kept on straw and roots in winter, and upon green fodder mown for them during the summer. Of course, the animals must not be allowed to graze on any portion of the artificial grass crops; but being fed in a shed or lodge, may have a small open space in which to move about for their health. It is found that not only the cow gives a great deal more milk when kept warm in a house, but that the land yields a much larger proportion of food for her than when she is suffered to depasture and trample it. Indeed, three roods, or half an acre of artificial grasses, according to the application of liquid manure to the surface after each cutting, will suffice to keep one cow. There may be more than one crop in a year on part of the land: say that rye is the first thing cut green in spring, dig the land, manure, and sow mangel and turnips; the next cutting is of winter barley and tares, which are to be followed by late-sown turnips and planted cabbages; and the Italian rye-grass and clover yield several successive cuttings in the course of a summer, by plentiful waterings with liquid manure.

A portion of ground is to be set apart as a garden for potatoes, parsnips, carrots, onions, cabbage, and various table-vegetables; a few currant and gooseberry bushes, and an apple-tree or two, a few flowers near the house, and perhaps a hive of bees, not being forgotten.

From many reasons, the spade is found to be a far more efficient cultivator than the plough; the soil is not only deeply broken up, for the penetration of the roots of plants and for the admission of fertilising rain-water and atmospheric air from which the soil is continually absorbing gaseous nutriment for crops, but it is more completely subdivided and pulverised; there is no glazed pan, as left by the sliding pressure of the plough, to oppose the descent of rootlets, of water and air; and by the more accurate inversion of the soil, the seeds of weeds and larvæ of insects which are about the surface are turned down and destroyed. The greatest advantage of spade-husbandry is in the trenching or very deep digging which can be practised. Instead of recruiting the productive power of the land by fallowing, as in ordinary farming, the cottage-husbandman brings up an under-stratum of soil to take the place of that which has been bearing a crop upon the surface. This layer, which we may call No. 2, lies, say from nine to eighteen inches below the surface, supposing a nine or ten inch spade to have been employed in the ordinary digging. After two or three years' cropping, a considerable portion of the manure delved in will have been washed down and imbibed by this lower stratum, and the upper layer will have been largely robbed of the mineral ingredients necessary for the sustenance of good crops. The art, then, consists of raising up this layer, No. 2, and turning down No. 1 in its stead. In some districts, the depth of available soil may not be so much as eighteen inches, the layer beneath being rock or chalk; in which case it will often be worth while to expend great labour

in gradually breaking it up with the pick, and incorporating portions of it with the upper soil. Indeed, in no case is it advisable to bury the top staple at once, and attempt to grow a crop upon the raw unmitigated, unameliorated subsoil brought up in its place; the principle is, to deepen gradually, bit by bit, and so, in effect, add to the extent of land cultivated without increasing the superficial area.

The Rev. Mr Smith, late of Lois-Weedon, Northamptonshire, obtained immense crops by following this principle, together with that of having fallow-intervals between the rows of cropping. By deeply burying farm-yard manure, and well dressing with guano, superphosphate of lime, &c. beside, he produced thirty-eight bushels of winter beans and fourteen tons of carrots upon the same acre of land—the beans being in single rows, no less than five feet apart, and the carrots in rows between. This he found very profitable; and besides interlining various other root or green crops with success, he grew wheat without a particle of manure year after year upon the same fields, with an average yield of thirty-four bushels per acre, and a profit of £5 per acre, with wheat at £2 per quarter. The wheat was in triple rows, one foot apart in the rows, with intervals of three feet. The intervals were dug two spits deep before winter, scarified in spring, and horse-hoed through the summer; this stirring being found to feed the corn-plants growing on each side, as well as prepare a fine and fertile seed-bed for the rows of wheat the following year. The wheat-rows and fallow-intervals succeeded each other alternately, the same strip being thus bare-fallowed every other year; and it was found from a long course of years, both on clay and gravelly land, that the annual produce, reckoned for the whole field, equalled that which other farmers obtain only once in two years. The cottage-farmer will do well to make himself acquainted with the particular directions laid down in Mr Smith's pamphlet, the *Word in Season*, and in his little book entitled *Lois-Weedon Husbandry;* as we believe tillage, such as that which a small occupier can accomplish with facility, has never before been brought to produce such remarkable returns, alike in produce and in a cleanly condition of the land.

In working a cottage-farm, unremitting industry is required; and it should be an object to make the very most of every day out of doors when the season and weather permit, and to occupy the dead of winter and days of bad weather at work in the barn or house. Trenching an acre two spits deep will take from thirty to thirty-five days; and one-spit digging ten inches deep, from twenty to twenty-five days, according to the nature of the soil. To make ridges for potatoes, plant the sets, mould them up with the hoe, and finally take them up, will take about twenty-four days for one acre. In digging, it should be borne in mind that a man can effect about one-sixth more work with a proper steel fork than he can with an ordinary spade.

In a Report of the Emigration Committee, published some years ago by the House of Commons, is the following estimate of the expense attendant upon the location of a family, consisting of a man, his wife, and three children, upon four acres of waste land fit for cultivation, in any part of the United Kingdom:

	£	s.	d.
Transport of the family—say, on an average, 50 miles—to their location	3	0	0
Implements	2	10	0
Household furniture	5	0	0
Cottage, cow-shed, and pigsty	26	0	0
Potatoes and seed	4	0	0
Provisions for one year	25	0	0
Cow, pig, and poultry	9	0	0
Proportion of the cost of superintendence	0	10	0
	£75	0	0

The items for the buildings and the live-stock are much too low for the present day, so that £100 will be nearer the sum required. It was considered that by the produce of the four acres cultivated by the spade, the family could maintain themselves, and, after a lapse of five to seven years, dispose of produce to the value of £22 per annum, after paying £8 yearly rent.

A cottager is described, in the *Cottage Farmer's Assistant*, as keeping two cows upon three acres of light land in Sussex, with the following results:

		£	s.	d.
278 pounds of butter, in 6¼ months, sold at 1s. per pound		13	18	0
Skim-milk, sold for 3 pints 1d. or given to the pigs, estimated for the year at		10	0	0
Two calves, sold for		5	18	0
Half an acre and 8 rods of land, yielding 19 bushels of wheat, at 8s.		7	12	0
A quarter of an acre, producing 14 bushels of oats, at 4s.		2	16	0
Making a gross produce off half an acre of pasture, and 2½ acres of arable, of		40	4	0
Rent, taxes, and tithes	£12 12 6			
Seed	2 0 0	16	12	6
Hired labour	2 0 0			
Making a clear profit of		£23	11	6

And the butter looked for in the remaining five-and-a-half months was expected to make a total gain, from the labour of the cottager and his wife, of £30.

We have not space to enter upon the subject of the use of the spade in conjunction with the plough on farms large enough to support a team of horses; but it is placed beyond a doubt, that more produce is raised for human subsistence—space, soil, and climate being equal—by small farmers using only manual labour, than by large farmers with horses and ploughs.

In these days of farming-capitalists, and the appliance of steam-power, not only to mill-work, but the tillage of estates, the claims of the poor to a share of land, and to independence, as a prospective reward for their industry, are not very likely to be remembered; but if it be true that the system of large tenancies, and still more of monopolised proprietorship, has not been able to prevent a decrease of our rural population, and an immense amount of pauperism, it becomes high time for the community to demand that the waste grounds be utilised, and the people provided with the means of earning an honourable livelihood in that healthy and ever-coveted employment—the culture of the soil.

THE KITCHEN-GARDEN.

GARDENING, whether regarded as an ornamental art, or as a branch of industry, has long been cultivated with success in the British Islands, and has, in fact, become more intimately identified with the English people than with any other nation. Happily, many advantages of a public kind are now afforded for the gratification of our love of gardening. The Royal Garden of Kew is now the everyday resort of pleasure-parties of all ranks of society—from the humble artisan, whose holiday comes once a year, to the rich noble, whose life is one long holiday. The Crystal Palaces at Sydenham and the Alexandra Park, the Regent's Park Botanic Garden, Battersea Park, and the 'marine gardens' (vivaria) of the Zoological Society, are additional sources of delight to all lovers of gardening in London; while the inhabitants of Scotland have the Royal Botanic Garden at Edinburgh, with its palm-houses, noble conifers, heaths, and ferns; and the Botanic Garden at Glasgow. Ireland is fortunate in its Botanic Gardens at Dublin, Belfast, and Galway. The provincial public institutions of this kind in England are numerous—as those at Cambridge, Oxford, Sheffield, Manchester, &c. To these may be added the gardenesque style of keeping now happily introduced into most of our public parks and cemeteries. But the possession of such examples of gardening does not satisfy the people; for gardens are like libraries—the enjoyment of a public one leads every man to wish for a little paradise of his own.

There are various kinds of gardens—the Italian gardens, with their splendid terraces, vases, and statues; the old French gardens of Le Notre, of which we have a specimen at Versailles, with their long straight walks, clipped hedges, formal parterres, and fountains; English gardens, with their elegant blending of natural with artificial beauty; and so on. But it is to none of these princely kinds of gardens that we intend, in the present series, to direct attention. We propose to treat of the three departments which belong to the greater number of gardens of the middle and humbler classes; those, in short, which, designed on a moderate scale, are intended to afford the three staples of garden culture—*vegetables* for the kitchen, *flowers* to charm the eye, and the more easily attainable kinds of *fruit*. These various articles are for the greater part the production of one garden, a section or scattered part being set aside for each; but for the sake of clearness, we shall confine ourselves in the present sheet chiefly to the economy and products of the kitchen-garden.

CHOICE OF SITUATION AND LAYING OUT OF GARDENS.

A garden of the ordinary mixed description varies from the eighth of an acre to a whole acre; but a common size in country places is about half an acre. Whatever be the dimensions, the garden ought to be inclosed with a wall from ten to twelve feet high, and the ground thoroughly drained. A much more important circumstance than size or external appearance, is exposure. In a flat country, the garden must of course be level; but if there be a choice as to situation, select by all means a spot which lies with an easy slope towards the sun at his meridian. In the British Islands this will be facing the south. The next best exposure is towards the south-west, and after that the west. Avoid a northern or eastern exposure. Allow no house, wall, or trees to interrupt the fair action of the morning sun on your garden; for the sun is the main agent in bringing vegetation to perfection, and if you be deprived of it, your operations will be blighted and retarded in every possible way. So important are the sun's rays, that if your garden be small, rather have no wall on the south and west sides, but only a low fence, than submit to their exclusion. Some gardens are so disposed that they receive the sun in abundance in summer, but only partially the rest of the year. These gardens are imperfect. The garden should be visited all over by the sun daily, except perhaps in the heart of winter, when his rays have comparatively little effect. The exposure should also allow a free admission and currency of air; for this reason, a garden is best away from dense old woods, and is most advantageously placed in an open sloping lawn, overlooked by, or near the house of the proprietor. There should be an abundant supply of water readily at hand, for 'water is the life and soul of a garden.'

The shape of a garden is of little consequence. It may be square, oblong, semicircular, or irregular, according to taste or local circumstances. In the greater number of instances, an oblong, as represented in the following plan, will be found most convenient. It is surrounded by a wall, in

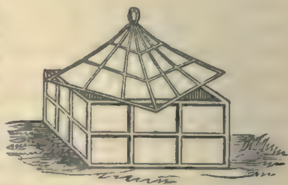
which is an entrance marked *e*. Within the wall is a border of several feet wide for select crops, or dotted round with flowers and flowering shrubs. Next is a gravel walk; and within is another border containing fruit-bushes, or perhaps fruit-trees on espaliers, and in the centre is the body of the garden laid out in three plots, marked *a*, *b*, and *c*. Between these plots and around them are paths (represented by dotted lines) of twelve or fourteen inches in width, not for ordinary walking, but for admission to the various plots or sections

into which the ground may be divided. These paths are only flattened by the foot or by the spade, and are to be delved up annually in the course of digging. At that side of the garden opposite the door there may be an arbour or summer-house fitted up according to taste and overhung with honeysuckle, jasmine, or other climbers.

The regular walks in all moderately sized gardens should not be wider than five to six feet, at least where land is of value; and each should have a three to four feet deep drain, formed under its centre where the adjoining ground is level, but under its upper side when that is sloping; an ordinary drain-tile being laid in the bottom, and then filled up with ashes, gravel, or other water-conducting substances. Much care is required to keep walks in order, for they are very liable to shew crops of weeds and moss. To prevent this, as well as to guard against worms, which are very apt to disfigure the walks by throwing up casts, it is a good plan to bottom the walks with nine inches in depth of broken stones, clinkers, rough cinders, or slag from furnaces. Over a smooth level bed of this kind put a layer of small gravel that will bind, or, failing this, a layer of brayed yellow ashes from a furnace, if they can be procured. Smooth all with the rake, and flatten with a roller. Such walks should be scuffled with the Dutch hoe, raked, and rolled down several times during the season, otherwise the growth of weeds and moss will render them untidy. On no account should such operations be neglected until *Poa annua* and other weeds have shed their seeds, otherwise it will be impossible to get the walks thoroughly cleaned. Many small plants—such as daisies, Gentianella, thrift, dwarf heaths; several kinds of whortleberry, and the bush or runnerless Alpine strawberry—are used for edgings to walks; but that most in repute is dwarf box-wood. Flints and other stones of different kinds, forms, and sizes, as well as frost-proof bricks of various patterns, are also very frequently employed for forming edgings, as they afford no shelter for slugs or other vermin, while they admit of the weeds being killed with boiling water, gas liquor, or other liquid applications.

The above remarks will suffice to indicate the mode of forming walks in a common kitchen-garden of ordinary dimensions. Where the garden is more extensive, and is intended as much for ornament as utility, more care will be required, for nothing conduces so much to the tidy appearance and comfort of a garden as the neatness and dryness of its walks, especially in wet weather. On flat ground, both verges or edgings of a walk should be on the same level; but where the ground is much sloped transversely, a fall to the lower side may be allowed of about a quarter of an inch to the foot. Where the walk takes a precipitate fall, it will be necessary to have surface tile-gutters along one or both sides, or channels formed of sea-pebbles may be used with good effect; but where edging-tiles are used, those having hollow water-runs underneath are more sightly and effective than open water-runs. Concrete or asphalt is sometimes used for the surface; but good gravel, where obtainable, is to be preferred. 'It is more congenial to our feelings, and harmonises better with the surrounding scenery of the garden.'

No precise directions can be given respecting garden tools and apparatus; the following are the articles required in moderately sized gardens of a mixed kind: Spades, a digging-fork, a trowel for lifting flowers, Dutch and common hoes, iron rakes, a strong clasp-knife for pruning, pruning-gloves, a pair of strong pruning-shears, an axe, a hand-saw, a hammer and cast-iron nails, a wheel-barrow, a roller, a dibble and line, a watering-pan, a scythe, a mowing-machine, edging and hedge shears, a ladder, flower-pots of different sizes, conical earthenware blanching-pots, bell-glasses, and hand-glasses of different sizes. These last may be had either in one piece or with a movable top, as in the following figure. A neat small kind, framed in zinc, useful for protecting early seedlings or flowers, may be had for 2s. 6d. each. Other utensils employed by gardeners—such as forcing-pumps to wash wall-trees, fumigating bellows, &c.—need not be particularised. A person possessing only a small garden will shortly discover by experience what are the articles required in his operations. The articles constantly in use are the spade, rake, and knife; with these alone many a small garden is successfully cultivated, and the amateur with whom economy is an object, will do well, in entering for the first time upon a little garden of his own, to begin with them, and allow experience to suggest further wants in the tool department. For gardens in which cucumbers and melons are to be grown, glazed frames and brick-built pits will be necessary. As already indicated, it is a great advantage for a garden to have a command of good fresh water for the purpose of irrigation, and also a small pond in which aquatic plants can be grown. If water is procured from a pump-well, it should be allowed to stand in the open air in a trough for at least a day before being poured on the plants. By this means it gradually acquires the temperature of the atmosphere.



A garden is in all cases laid out according to the taste or fancy of the proprietor; but there are certain general rules which all follow. The wall is reserved for fruit-trees. As fruit-trees require much air and sun, the borders must not be clogged up with bushes, peas, or any other tall vegetables. The borders should either be reserved entirely for the roots of the wall-trees, or contain only small articles which are delved up yearly, because the soil at the roots of the trees requires occasional renewal and loosening, and these operations cannot be done if the ground is encumbered with permanent plants. If a row of gooseberry or other small fruit-bushes be placed on the borders, they should be near the outside, and not less than ten feet apart. Let it be observed also, that flowering-plants should occupy the border most exposed to the sun; while horse-radish, and others naturally loving the shade, should be placed on northerly and easterly exposed borders, from which the sun's rays are generally less or more excluded.

The body of the garden within the walks is laid out in larger or smaller plots, according to taste.

These plots are generally subdivided into sections, rows, or beds, for the different kinds of kitchen vegetables. In the corner of one plot are the cucumber and melon pits, partially secluded, but not shaded by hedges or bushes, and round the edgings are the flower-parterres, disposed to meet the eye, and to be easily accessible from the walks. In some gardens much of the ground is overshadowed by fruit-trees. This is seriously detrimental to the growth of the plants beneath, exhausts the soil, and prevents the proper development of every vegetable within reach. The only allowable places for trees are the walls and narrow espaliers running up one side of the central plots. When a garden possesses the addition of an outside strip, inclosed by a hedge, the exterior sides of the walls may be lined with fruit-trees, and the ground laid out for potatoes and other common vegetables; it will also afford the most proper site for compost dung-heaps, forcing-pits, and the like.

PREPARATION OF THE SOIL—COMPOSTS—TRENCHING.

The soil of a garden should be deep, rich, and easily penetrable. Whatever it may have been originally, the soil admits of vast improvement, and no trouble can be considered too great to bring it into a good condition. If shallow, trench it so as to loosen the subsoil and gradually bring it into operation above. In many instances the soil is too stiff or clayey. Such a soil may not be unfit for plough husbandry, but it is out of place in a garden. The method of loosening and meliorating a clayey soil, is to give it a large volume of sand and vegetable manure, which may be delved in at the winter and spring diggings. In general, too little attention is paid to adding sand as a restorative; such is absolutely necessary in all soils except those of a very sandy nature, because every crop actually carries away a certain proportion of the silica lodged in the soil. If the soil be already too sandy, it may be assisted by clay, silt from ditches, &c. Whatever be the nature of the soil, it should be thoroughly pulverised. Lumps thrown up by digging at the commencement of winter are pulverised by the frost, and imbibe nutritious gases from the atmosphere. In spring, all should be well delved, every spadeful being cut and broken as it is turned down, and no hard part left impervious to the tender roots of the vegetables. Every particle of soil should be capable of doing duty in feeding the plants.

No garden can be conducted with advantage without giving it regular and plentiful manuring. If you hunger a garden, it will hunger you in return; and there is no truer economy than, by abundant manuring, to make a small garden yield more than a much larger one in which it is grudgingly applied. In connection with every rightly managed garden, there must either be a compost-heap, in which dung is preparing for use, or there must be some means of readily purchasing old manure when it is required. The manures employed are the same as in agriculture; but being required for a more delicate purpose, they must in general be well rotted, and ready to unite with the soil. A compost dung-heap is prepared by putting alternate layers of stable-dung, or night-soil, &c. with earth, peat-moss, decayed leaves, and general refuse of vegetation; turning the whole occasionally till the mass appears to be sufficiently decomposed for use. A small quantity of this stuff will often be required to place at the roots of plants. Guano and other top-dressing manures should also be frequently, but not over-abundantly applied.

Near large towns, where there is a constant demand for kitchen vegetables, market-gardens are established for producing the required articles in variety and abundance. The finest market-gardens in the world are near London, where the soil is deep, and any quantity of manure from the metropolis is easily obtainable. The plan on which these gardens are conducted might serve as a model for all kitchen-gardeners in this country. It is thus briefly described in the article Gardening in the *Penny Cyclopædia:* 'The gardeners' year properly begins in autumn, when the land is dug, or rather trenched, and well manured. Various vegetables which will be required in winter are now sown, and especially those which are to produce plants to be set out in spring: spinach, onions, radishes, and winter salads are sown, and when the weather is severe, are protected by a slight covering of straw or mats. In February, the cauliflowers, which have been raised in frames or under hand-glasses, are planted out. The cabbage-plants are pricked out. The radishes, onions, and salads go to market as soon as they are of sufficient size, and sugar-loaf cabbages succeed them. As the cauliflowers are taken off, they are succeeded by endive and celery, and the same is the case with the cabbages. Thus there is a constant succession of vegetables, without one moment's respite to the ground, which, in consequence of continual stirring and manuring, maintains its productive power. Deep trenching in some degree prevents that peculiar deterioration of the soil which would be the consequence of the frequent repetition of similar plants. This effect is most perceptible when the plants perfect their seed, which is seldom or never allowed to take place in market-gardens; but great attention is paid to the species of plants which succeed each other on the same spot. Those gardeners who overlook this, and repeatedly sow or plant the same kind of vegetables in the same spots, are soon aware of their error by the diminution of the produce, both in quantity and quality, and by various diseases, as well as insect pests, which attack the plants, however abundant may be the food supplied to them, or however careful the tillage. The principle on which the gardens are cultivated, is that of forcing vegetation by means of an abundant supply of dung, constant tillage, and occasional watering.'

'The value of the produce in one year from an acre of garden-ground in the most favourable situation, as stated by Mr Middleton, from the account which he received from a market-gardener, is almost incredible. It is as follows: Radishes, £10; cauliflower, £60; cabbages, £30; celery (first crop), £50; (second crop), £40; endive, £30: making a total of £220 for the gross produce of an acre in twelve months. The expenses of cultivation are no doubt great. In inferior situations, the produce is much less, but the expenses are also somewhat less. When it is considered that there are nearly 2000 acres thus cultivated, the gross amount of produce must be very great.'

GENERAL OPERATIONS.

Digging or *delving* with the spade is the principal means of garden culture. The spade usually employed is ten inches deep in the blade or spit; but as delving is not direct downwards, but sloped, the depth to which the spade goes is seldom more than eight or nine inches. In commencing to dig a piece of ground, take out a spadeful all along one side, and carry it to the opposite side where you are to leave off. Now begin at one end of the trench just opened; thrust the spade with the foot into the ground, taking about five inches in breadth, lift it up, and turn it over into the open trench, the top undermost, and the fresh earth above. Do the same with the second spadeful; and so on with all the others to the end of the line. Take care to dig always a uniform depth and breadth, so as to keep the line even, and the trench or open furrow of one width. If there be any young annual weeds or loose refuse on the surface, bury them in the bottom of the trench; but where the ground is dirty with seed-bearing or root-spreading weeds, such ought to be well rotted in the dung-pit, or, what is better, reduced to ashes, and then spread over the soil. Break or pulverise the mould as you proceed, and keep the fresh surface level. When you have delved row after row to the last, the earth laid aside will fill up the concluding trench. Ordinary digging is performed best in dry weather; but digging to throw up lumps for winter melioration should, if possible, be performed when the soil is somewhat moist. In this kind of digging, do not touch the lumps with the spade after throwing them up; for the more rugged and uneven the surface, the more thorough is the exposure to the influence of the frost.

Raking.—Hold the handle of the rake at an angle of forty-five degrees, and draw it lightly over the surface of the newly dug ground. The object is not to draw earth along, but to smooth or comb down the irregular surface, and to bring away any loose refuse or stones. Like digging, it should be performed in dry weather.

Marking with the Line.—The gardener measures and marks off all his figures in the ground with his line and spade. With the line he can draw a circle round a central pin, or make an oval from a union of two circles, or form semicircles, spirals, triangular spaces, or polygons. It guides him in forming drills for seeds, as well as in putting out young plants, and when he wishes to make a small path between rectangular plots, he sets his line accordingly, and walking along it, with a foot on each side, he tramples down the earth, from one end to the other, and then he can smooth it and beat it down with his spade.

Hoeing.—With a common hoe, the earth is cut and drawn towards the operator. The object of hoeing is to draw up the earth so as to cover the lower parts of the stems of plants growing in a row. In hoeing weeds, which is done by a different implement, the Dutch hoe, they are cut off beneath the surface, raked away, and placed on the dung-heap. Weeds, especially such as dandelion and groundsel, whose seeds become winged when ripe, should be hoed and removed before seeding. As many such weeds which infest gardens are blown into them from adjacent roadsides, it would not be misspent time to clear the neighbourhood periodically.

Animal Annoyances.—All gardens are more or less exposed to the destructive inroads of wild animals. Hares and rabbits not only gnaw the bark off the stems or lower branches of trees, and also the buds in season, but are also very destructive to vegetables and flowers. To prevent the encroachments of these quadrupeds, the garden ought to be properly fenced; but if they get in notwithstanding, the trees may be saved by smearing the lower parts with a mixture of cow-dung, soot, and water, reduced to the consistency of thin paint; a smearing of tar or animal fat will also answer the purpose. Moles, rats, and mice may be caught by trapping; moles also are said to be got rid of by placing slices of garlic, or onion, in a green state, within their holes, as they have a great antipathy to the odour of these vegetables.

Birds are sometimes an annoyance, particularly when new-sown peas or seeds may be easily scratched up. But, though in some instances injurious, it is believed that on the whole their visits are beneficial; for they pick up large quantities of slugs, insects, larvæ, or caterpillars of different kinds. Wall-fruit may be preserved by nets, or by the more simple method of fixing horizontal lines of black worsted in front of the trees; the repeated ineffectual attempts to alight on these lines are said to scare the animals, and cause them to desist. Strawberry and bush fruits may also be protected by suspending either hemp or wire nets over them. Lines of threads, along which feathers are fastened, are employed in many cases to protect beds of seeds from birds, but are only partially successful. Coating seeds with red-lead, by wetting, and then mixing them in it, is a good preventive against birds and mice.

Insects are the grand pests of gardeners; their appearance is so mysterious, and their devastations so varied, that all schemes to extirpate them are often ineffectual. They are most destructive in their first condition of larvæ or caterpillars. In this state they should be removed by the hand from kitchen vegetables. To destroy the smaller kinds of larvæ, fumigation of tobacco-smoke, by means of a fumigating bellows, may be employed with advantage; and the plants may be cleansed with a syringe and water. For the cleansing of fruit-trees from insects, we refer to the article on FRUIT-GARDENING.

Slugs are another chief annoyance, especially in low-lying shaded situations. A little salt destroys them, as does also a sprinkling of quicklime, or diluted gas-water, when they are abroad at night; but, as in the case of caterpillars, the best plan is to clear them out on their first appearance, by the hand, from pieces of cabbage-leaves, previously laid about to entrap them. Worms in the ground are not considered injurious. Salt kills them.

Sowing.—The greater number of garden vegetables are reared from seeds, which are sown at certain seasons in the ground. Some seeds, such as peas, are sown in drills, the hand deliberately dropping them in a straight shallow trench. Other seeds, such as onions, leeks, cress, &c. are sown either in drills, or broadcast in beds, and covered with a thin equal scattering of earth. There is no necessity for any species of sowing-machine in a common kitchen-garden. Most seeds, peas included, require to be pressed down,

by treading or gentle rolling, and then covered up by the hoe or rake. All seeds should, if possible, be sown and covered up in dry weather.

Planting.—Many vegetables require to be removed while young from the bed in which they were grown from seeds, and planted out in rows. Having adjusted the line, commence at one end of it; pierce the earth with the dibble, and into the hole so made, insert the root of the plant, then pierce the earth at its side, so as to press the mould round the root, leaving no vacant space below. The common errors in planting are injuring the tap-root and rootlets by careless pulling of the young plant from the nursery, by rudely using the dibble, or by pressing the earth too firmly round the collar, and neglecting to do so with the roots.

Watering.—In dry seasons, artificial irrigation is of great use for giving due liquid aliment to plants, and is indispensable to those newly transplanted as above. Watering, for whatever purpose, is most advantageously performed in the morning or evening. If done during the time the sun is shining, take care not to water the leaves of any plant. If the day be cloudy and cool, watering the tops of plants can do no harm. Watering overhead should resemble as nearly as possible a soft shower, and be performed with a rose watering-pot. The greater number of flowers are injured by watering, if the water touches their petals.

KITCHEN VEGETABLES.

The vegetables usually grown in kitchen-gardens belong to various natural orders, which, for convenience, we shall arrange in the following groups—1. The cabbage tribe of vegetables; 2. The pea and bean kind; 3. Those grown for the sake of their roots and tubers; 4. The onion and leek kinds; 5. Salads; 6. Sweet herbs; and 7. Miscellaneous kinds. This grouping, it will be understood, has only a partial reference to botanical arrangement, and has been adopted in preference to the confusion of common alphabetic lists. For the technical classification of the plants here treated, the reader is referred to the sheets on SYSTEMATIC BOTANY.

The Cabbage Tribe.

The vegetables of this group belong to the order Cruciferæ, having cross-shaped flowers, and have, in fact, been all derived from the one plant, *Brassica oleracea*, which grows on the shores of the south of England. Its garden varieties—cabbage, savoy, Brussels sprouts, cauliflower, and Scotch kale—all so unlike each other, and so unlike their indigenous prototype, present a series of the most remarkable instances known of the power of man to induce modifications in the size, form, and structure of an organic being, and to sustain permanently the races thus obtained.

Cabbage (*White*).—The cultivated varieties of the common or white-hearting cabbage are very numerous. The best varieties in ordinary use are—Small and Large York, London Market, Sugar-loaf, Enfield Market, Wheeler's Cocoa-nut, Battersea, Vanack, Drumhead, Sutton's Imperial, Atkin's Matchless, Williams' Early Nonsuch, Sandringham Sprouting, M'Ewen's. To obtain hearted cabbages throughout the year, two or three sowings must be made; one in the spring, another in summer, and, finally, one in autumn. Spring sowing can be effected at once, or it may be divided into two or three operations; from the third week of March to the first week of May, for the supply of summer and winter. Yet, by attentive management, one sowing may be made to produce all that a family can require: we restrict our directions to that simple operation.

As with the other *Brassicæ*, one ounce of cabbage-seed is sufficient to sow a bed ten feet long by four feet wide broadcast, or fully a half more when sown in drills, which is the preferable mode; and is done thus:

Select a piece of good sound loam in an open exposure, and let it be slightly manured. Dig the ground for four rows, nine inches asunder, and from fifteen to twenty feet long. Break the earth finely, and leave it to settle for three or four days; then place boards to tread on, while a first drill, one inch deep, is struck by hoe and line; make the bottom of this and every other drill even, and a little solid, by patting it with the back of the rake. Sow the seeds rather thickly, because it is better to thin out an abundance of plants than to lose the greater part of a thin crop by insects. When sown, cover the drill with fine earth, proceed to make and sow other drills, till the bed be finished, and then either tread the surface over with the feet placed nearly close together, or pat the surface with the spade, and finish it off smooth with the back of a rake. Always avoid to tread ground into holes, and therefore recede from the work backward. In a very dry season, seeds will not easily vegetate; therefore in such cases strike the drills, and water effectually along them for three successive evenings, covering the plot with mats throughout the day. In the third evening, make the drills even, sow, cover with earth, sprinkle again, and lay on the mats by day, till the plants be visible, then dust them once with the finest road-dust while the dew is on, and in the evening with air-slaked lime. These precautions need not be repeated. We never saw a set of cabbage, turnip, or celery plants so dusted that was much infested with the turnip-beetle or slugs.

When the plants begin to produce their true leaves, thin them out, first to an inch asunder, and again to two inches; they will thus gain strength rapidly; and when they have three or four good leaves four inches long, they will be fit to plant out, some into nursery-beds, and others to the plots where they are to remain. Those set in the former, six inches asunder, will acquire stocky roots, and be prepared for successive plantings. Those planted permanently will require the ground to be made rich with manure, and the transition from poor to rich earth will make them grow rapidly. The smaller Yorks, &c. should stand twelve or fifteen inches apart; the large varieties, twenty to thirty inches. Set each plant as deep as the base of the lower leaves, keep down weeds by deeply hoeing or stirring the soil, and earth up the rows when the plants are sufficiently advanced.

Red Cabbage is only used for pickling; it is raised by sowing in August, and transplanting, as directed above. The heads form in the ensuing summer, and are in fine condition in October. If sown in spring, little-hearted cabbages can be obtained, which may supply a loss, or serve as a

substitute for the others. The large or Dutch red is the best.

The Savoy is very hardy, and, like the cabbage, forms a close round head, but the wrinkling of the leaves serves to distinguish it. Its leading varieties are the Cape, Drumhead, Ulm, and Little Pixie. Choose the ground, and sow as directed for cabbages, making the first sowing in February, a second in March, a third—and this is for the main crop—in April, about the middle of each month. Repeat, for the fourth time, in August. The plants of this last sowing will attain a large size by the following August and September, if planted out in April. Moist weather should be chosen for planting, and the savoys should stand two feet apart. Keep the ground clean, stir it occasionally, and draw the earth towards the stems on each side, leaving a sort of furrow three or four inches wide on the top, to receive the rain, and convey it to the roots.

Brussels Sprouts produce stems from two to four feet high, each of which supports a head somewhat resembling an open savoy, of little value. But lateral buds down the stem develop into a succession of little green heads, like small savoys, of delicate flavour. The most noted kinds of this delicious winter vegetable are the improved tall, dwarf, Scrymgeour's giant, and the Dalmeny hybrid. Sow in spring and August, as with savoys, planting out the dwarf kinds about eighteen inches, and the tall sorts twenty to twenty-four inches apart.

Kale and German Greens.—These are raised by sowing the seeds either in beds or single drills late in February, or early in March; to be first thinned out to three inches apart, and finally transplanted to beds or rows, wherein the plants are to stand thirty inches asunder. The plants may go out in succession from June to the middle of July. The heads are cut first, and subsequently side-shoots arise, which produce excellent winter greens till early cabbages come in. The kinds are: Scotch, Kilmaurs, Siberian or Lapland, cottagers' and asparagus kales; tall and dwarf German greens.

Cauliflower, which is grown only for its rich white heads of metamorphosed flower-buds, is one of the most delicate and highly appreciated products of the *culinarium*, and requires protection from hard frosts. The kinds are: Asiatic, early London, late London, Frogmore early forcing, Veitch's autumn giant, and Walcheren.

Spring sowing, for a first crop, may be made in March, over a temperate hotbed. The seedlings are to be pricked out under shelter when the leaves are an inch broad; and from this nursery-bed they are moved to the garden in May, to stand fully two feet asunder, the ground being made extremely rich. The plants, after they begin to grow, are occasionally watered with the liquid manure collected from the drainage of dunghills. A second spring sowing is made in the open border in May, to obtain plants from September to November, by a similar mode of treatment. The last sowing occurs in the middle of August, and its plants, when about four or five weeks old, are to be thinned out to two or three inches apart, the best to go into nursery-beds of rich earth, three or four inches asunder. Here they must grow till November, when the strongest are to be set out in rows, to be preserved under bell or hand glasses. Dig a piece of rich ground in an open situation, making it still richer with manure; set three or four plants together, five inches apart, in patches, each patch a yard asunder; give water, and cover close with a hand-glass till the plants begin to grow. When fairly taken with the soil, tilt the glasses on the sunny side with a brick, and thus continue to give air on mild days during the winter, and on some occasions take the glasses quite off, but replace them, and cover close every night. In the spring, thin the plants to two under each glass, making good any deficiencies with some of the best plants thus taken up, and plant the surplus in a warm spot of ground two feet apart. Keep the glasses on the other plants, raising them more and more, occasionally exposing them to mild rains till about the middle of May, when the glasses may be finally removed.

Other August-sown plants should, in November, be placed in frames four inches apart, in a bed of rich dry loam, over a very slight hotbed: give water, close the lights, and be guided as respects the admission of air by the directions for the hand-glass division. The lights should be covered with mats and boards during severe frosty nights. In March, April, and May, these plants are removed in succession to richly prepared ground, and the cauliflowers will come into perfection during July and August. In earthing up it is a good practice to leave small basins around the stems for holding liquid manure, and this, with hoeings between the rows, comprises the general treatment.

Broccoli is one of the best vegetables of the cabbage kind, and is valuable for coming at seasons when not liable to be affected by caterpillars, and when culinary vegetables are comparatively scarce. There are various kinds of broccoli, but all may be arranged under two heads—those for spring use, and those for use from September to Christmas; the latter are termed 'Cape' or autumn broccolies, of which may be named the white and purple Cape, Dancer's pink Cape, and Grange's early white. The most approved varieties for spring use are the 'protecting' broccolies of different kinds, so called from their leaves being folded cabbage-like over the head; Miller's dwarf, white sprouting, purple sprouting, Williams' Alexandra, late purple, Cattell's eclipse, Chappel's cream, Dalmeny Park, Shearer's late white, and Portsmouth cream or buff-coloured.

The soil should be a fresh and rich sandy loam, and the season for sowing will be comprised between April and July. The plants of the Cape kinds are finally set out in beds made rather rich with manure, at any time when they have leaves a few inches long; two feet distances, plant from plant, will be sufficient. These will come in season in August, and continue to produce a supply throughout the autumn; in mild seasons, some heads may be cut even so late as the end of the year.

The spring hardy varieties are treated in the same way as the Cape—that is, the plants, when they are six or eight inches high, are transplanted as they become ready, between the first week of July and that of September, into richly manured ground, and set in rows two to three feet apart, the largest sorts, as the Portsmouth, at thirty inches, and the dwarfest, as Miller's, at eighteen inches. If the seasons be favourable, a successional supply of broccoli is thus obtained

from the first week of March to the end of May. It is also customary to lay down plants in September, with the heads turned from the sun, applying earth on the south side over the stems, to protect them from snow and frost.

The Leguminous or Pea and Bean Tribe.

Of the Pea there are various sorts, but it is only those of a fine kind which are cultivated in gardens, and called *garden-peas*, that we require to notice here. When fresh, they are a bright green, and when dry for seed, most are a buff yellow, others of a bluish-green hue. Peas are a summer delicacy, and the chief art is to produce them in the open air, by the middle of May, and to keep up a succession of crops till the weather becomes too cold for them in autumn. Skilful gardeners do not consider it a difficult process to effect an early crop, as the plants are very hardy, and sustain violent transitions without much danger. Peas, therefore, may be accelerated in frames and vineries during February, and transplanted into rows fronting a south wall, where they will continue to advance steadily though the weather be cold. They can also be sown—provided there be no frost—in the open ground at any time throughout the winter. There are many varieties of this vegetable, but we shall notice only those that have proved themselves worthy of general culture. Beck's Gem, Easte's Kentish Invicta, Essex Rival, Laxton's Alpha, Laxton's Supreme, M'Lean's Little Gem, Sutton's Ringleader, Multum in Parvo, Nutting's No. 1, and Prince Albert, are adapted for very early crops; but some of the following later kinds ought to be chosen for a full crop: Imperial, Knight's Marrowfats, Fairbeard's Surprise and Champion of England, Advancer, Laxton's Quality, Princess Royal, British Queen, Burbridge's Eclipse, Harrison's Perfection, M'Lean's Premier, Prince of Wales, Queen of the Marrows, Veitch's Perfection, Williams' Emperor of the Marrows, Wonder of the World, &c. In the two varieties of sugar-pea—the tall and dwarf—the pod is destitute of the cartilaginous transparent lining usually seen in the pods of peas; this enables the pods to be used in the same way as those of kidney-beans.

The soil in which peas most luxuriate is a free, light, but rich loam, abounding with vegetable matter, but not manured with recent dung. The situation for crops from June to August should be exposed and open. Some obtain an excellent yield from seed sown early in November, in a sheltered situation; and if the winter be open, success is nearly certain. At whatever season sowing is commenced, a better general rule cannot be adopted than to sow for a successional crop as soon as the peas of the preceding sowing are fairly above the surface. The plants, when three inches high, should have earth drawn against their stems on both sides; after which, the soil may be superficially opened by passing the hoe lightly through it, and thin branchy sticks, or other supporters, of a height suitable to the habit of the variety, ought to be thrust into the ground, converging a little so as to meet at top, and interlace each other. Shallow soils over chalk are soon over-cropped by peas, and refuse to bring a healthy plant; and in all kinds of ground, the frequent repetition of pea-sowing is to be deprecated.

In country gardens, the field-mouse is a great enemy to peas, and where these are sown in winter or early spring, when food is scarce, the seed is sure to become a sacrifice to its ravages. Many methods have been recommended to obviate this mischief; but the most effectual plan is to coat the peas with red-lead, then to make a pretty deep furrow, and after depositing the seed-peas in it, to cover them with small bits of chopped furze, after which the whole is covered in with earth in the usual manner.

Kidney-beans.—These are planted in rows, and the seeds are generally sown at different periods between the 1st of May and the middle of July. The situation should be open, not crowded by other vegetable crops, or under trees—the soil, a free working loam, moderately manured. The drills should not be nearer to each other than thirty inches, and not more than two inches deep. In these the beans are to be dropped at regular distances, not exceeding three or four inches. Make the ground firm at bottom, but let the covering earth be light, and only slightly raked, not trodden or made hard. The one leading principle of successful growth, is to bring the plants up as soon as possible, and this is effected by selecting warm weather and well-prepared open soil. A cold, wet, cloddy condition of the land causes decay.

The kidney-bean comprises two species of plants, which, though of one family, are of very different habits. Both, however, are natives of the East, and are very impatient of cold; hence the necessity of deferring the sowings till the weather be nearly settled in the spring, and the ground warmed to the depth of several inches. The two species are, first, the *dwarf*, with its numerous varieties, all bearing the title of *French-beans*—being forms of the *Phasœolus vulgaris* of botanists—and, secondly, the *runners*, which are varieties of the *Phasœolus multiflorus*. There are few of the many varieties of the dwarf which surpass the buff or dun-coloured in its freedom of growth and fertility, either when forced in pots or planted in the open ground. The black speckled, negro, and American prolific are also excellent bearers; the white is the true *haricot* of the French.

Runner Kidney-beans are planted with similar precautions, or if sown early in pots and boxes, will transplant very well. When the plants attain the height of three or four inches, they should have a little earth drawn about the stem, and be staked; that is, somewhat tall branchy sticks should be placed on each side, converging towards each other at the top: these props ought to be eight feet high; and when the plants reach their summits, they should be nipped off and kept stopped, to cause them to produce fruit-bearing laterals. 'Gather beans, and have beans;' that is, never leave any pods to ripen; if redundant, let them be given away, or go to the pigsty, for a maturing pod arrests the fertility of the plant by tasking all its powers. Keep the crop clean, and the surface of the ground rather open. The kinds are: Scarlet Runner, Painted Lady, Carter's Champion, and White Dutch.

The Garden-bean is known to every one. Though a native of Egypt, it is, in all its cultivated varieties, very hardy. These varieties are numerous: some of the more approved are—the Early Mazagan for the first crops, which may be sown from October

to February; Early Long-pod, an excellent fertile bean for general use, not highly flavoured; Johnson's Wonderful Long-pod, Green Long-pod, White or Broad Windsor, the best of all beans for flavour; Green Windsor, Beck's Green Gem, and the Dwarf Fan or Cluster, which produces an abundant crop in little space.

Beans prefer a sound firm loam, retentive of moisture, and suffer in a very dry season and soil, particularly if attacked by the black 'green-fly.' They should be sown at four to six inches apart, in two and a half to three feet wide drills. Beans transplant well, and therefore may be sown thickly in autumn, the plants being covered with hoops and mats, or with a garden-frame and lights. When the plants rise in the rows, or begin to grow after being transplanted, loosen the earth by pushing the Dutch hoe along the surface, and draw three inches of it to each side of the stems; or rather, shovel up two or three inches of the earth, and lay it flat a foot wide on each side of the row of beans, shelving rather towards the stems than from them, for then the rains would find their way directly to the roots. The seasons of sowing are autumn for the Mazagan, January and February for long-pods, and from March to June for the Windsor. Sow succession crops one after the other, according to the demand, as soon as the plants of the preceding sowing shall be quite above ground.

Lentil.—Within the last few years, this crop has attracted some attention; it is, indeed, the oldest leguminous plant of which we have any record. For bread and pottage of lentils, Esau sold his birthright, and it is still in common use in eastern lands, being parched in frying-pans, and commonly sold in the shops in Egypt and Syria. The following varieties have been introduced: 1. Large; 2. Common or yellow; 3. Red or small brown; 4. Common small. This crop requires a dry warm soil, and might be advantageously grown in sandy situations unsuitable for common garden crops. The seeds should be sown pretty thickly in rows at 18 inches or 2 feet apart. One plant produces from 100 to 150 pods, each pod containing two or three seeds or 'lentils,' which may be cooked in the manner of peas.

Root Vegetables.

The vegetables grown for the sake of their roots are of two kinds—1. Those in which the roots are more or less round or lumpy, including the Jerusalem artichoke, the potato, and the turnip; and 2. Those which are tap or taper rooted, including the carrot, the beet-root, the radish, and the horse-radish. Strictly speaking, the tubers of potatoes, &c. are not *roots*, but merely underground concentrated stems of the vegetable, the real roots being small fibres which shoot out from the tubers, and bring nourishment to the whole. All require depth of soil to penetrate, and also looseness and breadth of mould to allow of expansion.

The Jerusalem Artichoke has no relation to the true artichoke; but is so named from its similarity in flavour to that esculent; while its first name is merely a corruption of the Italian name of the sunflower (*Girasole*), of which it is a species. The tubers, which alone are eaten, are produced abundantly under the surface, close to the base of the main stem. The plant is set like the potato, by either whole roots or cuts with one or more eyes to each. The pieces or cuts should be prepared at the time of planting, and set in shallow trenches two and a half to three feet apart, and fifteen inches asunder in the row. The season for planting is in the first dry weather of March; and half a peck of tubers will plant a row 120 feet long. A good mellow loam is the proper soil, and the spot for planting should be a sheltered, warm sunny exposure. The roots are perfected in October or November, and should be dug only when wanted, if that be convenient; but if not, lift the crop, and store away for winter use in moist sand or any kind of light soil through which the frost cannot penetrate. There is a French variety, with smaller, yellowish-coloured roots, which are reputed to be more delicately flavoured than the common kind.

The Potato, like the Jerusalem artichoke and some other plants, is a naturalised exotic in English gardens from the wilds of South America, and has been greatly improved by culture within the last hundred years. There are many varieties, individually distinguished by colour and flavour; and as some are better than others, it is very important that proper sorts should alone be cultivated. There are two distinct races—*early* and *late*. Early potatoes soon come to perfection, and few of them retain their good-eating properties when stored for future use; hence their culture is usually restricted to what is needful for summer and autumn. The leading kinds are Ash-leaved Kidney, and its sub-varieties, Bresee's King of the Earlies, Early Coldstream, Early Daintree, Early Oxford, Early Rose, Handsworth Prolific, and Mona's Pride.

Late potatoes, including intermediate kinds or 'second earlies,' are used in autumn, and onwards throughout winter and spring till about the middle of summer. The first four in the following list are specially suitable for using in autumn; the next four in winter and early spring; while the last five are best for using from the middle of March till full supplies of the earlies of next crop are obtainable: Early Shaw, Dalmahoy, Ash-top Fluke, and Wheeler's Milky White; Lapstone, Sutton's Berkshire Kidney, Rintoul's Regents, and York Regents; Late Rose, Skerry Blues, Fluke, Paterson's Victoria, and Sutton's Red-skinned Flour-ball.

The potato may be cultivated either by seeds procured from the apple, or from the tuber itself. If from the seed, the first crops of tubers are only a little larger than peas, and several seasons are required to bring them to an edible size. The common method of cultivation is by pieces or cuts of the tuber, each having at least one well-defined eye; cuts with two eyes are generally preferred. These are set in trenches, the ground being in good heart with previous manuring, or good old manure placed in the bottom of the furrow along with the sets. The season for planting is from February till late in April. Dig and plant sets, fresh cut as the work proceeds, placing the sets from nine to twelve inches apart, and the rows about twenty to thirty inches asunder, according as the kinds are of dwarf or tall growth. When the shoots have risen sufficiently above ground, stir the soil deeply, and earth up the drills with a hoe. Constant

stirring of the soil, and earthing up, is the great point in potato culture. (For further information on potato culture, see AGRICULTURE.)

Of the Turnip there are two races—the Common and the Swedish turnip: of the former, the leading varieties grown in gardens are—the Early White Dutch; the Yellow Dutch; Golden Stone; Yellow Malta; Orange Jelly; the Entire-leaved Red-top; and the Black Turnip. The white is the most delicate while young; the yellow Dutch has also an excellent flavour. Of Swedes, the best garden variety is Laing's entire-leaved yellow, but all the field sorts may be used if sown a month or so later than in field-culture. They are preferable for using in winter and spring. Turnips are sown in drills one foot or more apart, and thinned when two or three inches high. They do best in lightish soils enriched with bone-dust, guano, or good old stable-dung. Small sowings should be made in succession from March till July, and then the main crop for winter should be sown. Swedes should be sown in May. Deeply hoe the ridges after thinning, and keep the surface clear of weeds. The young leaves, 'turnip tops,' form excellent greens in early spring, and when blanched they are good substitutes for sea-kale.

Of the Carrot, the favourite varieties are the Early Horn, the Altringham, Long Red Surrey, Short Intermediate, and James' Intermediate. All require a deep light soil. The early horn is sown in February for the spring crop; the other kinds are sown in March, April, and May. All may be sown broadcast in beds, but drills are preferable, as being easier cleaned. For sowing, choose a calm day, as the seeds are very light; they should also be rubbed between the hands along with some dry sand or wood-ashes, to separate them, and so facilitate an equable sowing. Carrots may be stored like potatoes in winter; and it adds materially to their preservation in a sound and sweet condition, to riddle over the layers a few barrowfuls of dry mould or sand. The Altringham is best suited for a full garden crop.

The Parsnip is taper-rooted, resembling the carrot in shape, and by many it is deemed a more delicious vegetable. It requires a rich deep soil, trenched and manured as if for a crop of carrots. The seed is sown in drills a foot asunder. The period of sowing is comprised between the last week of February and the first week of May. On thinning out, let the remaining plants be nine inches apart in the row. Parsnips are not liable, like carrots, to be injured by severe weather; but if taken up before Christmas, and properly protected, they will continue good till May.

Of the Radish there are numerous varieties generally cultivated. According to Lindley's catalogue, these are—1. The long white; 2. Purple or salad radish; 3. Salmon or rose-coloured; 4. Scarlet; 5. White Russian radish; 6. Crimson turnip-rooted; 7. Early white; 8. Purple turnip; 9. White turnip; 10. Yellow turnip; 11. Black Spanish; 12. Brown oblong; 13. Large purple; 14. Round brown; 15. White Spanish, a large bulb, which in good soil grows to the size of a small stubble turnip. To this list have since been added the oblong or olive-shaped white and red, which yield to none of the others in earliness and excellence.

Numbers 2 and 3 are the best of the spindle-rooted radishes; numbers 6 and 7 of the early turnip-rooted. The winter radishes, 11 and 15, are rarely seen in gardens; but the latter is very mild, and its texture is tender, if the soil and season be favourable.

Sown in February and March, the spring radishes come into use in April and May; if required earlier, they must be protected by frames or mats. The market-gardeners obtain them early by gentle forcing, covering the beds every severe night. The sowings of all the early varieties may be repeated monthly till August. The winter radishes are sown in July and August, and come into use from September till the spring. A rich and light soil suits the radish, with occasional copious supplies of water; and rapidity of growth is required, otherwise the roots will not be tender, nor will the flavour be mild.

Spottiswoode's Rat-tail Radish.—In 1856, a remarkable kind of radish was raised in the Edinburgh Botanic Garden from seeds sent from India by Mrs Colonel Spottiswoode. It is called the Rat-tail Radish, and the edible part or 'radish' is not the root, but the young seed-pods. It produces a very abundant crop, and is well suited to the climate of Britain. Sow in April, in rows 18 to 24 inches apart, and thin out the young plants to from 12 to 15 inches. The pods are very delicate, and well adapted for summer and autumn salads.

Horse-radish is a plant which in most soils is of uncontrollably luxuriant growth; it is a most pernicious weed where it intrudes, on account of the multitude of vital germs with which its root-stock abounds, and by which it is rendered a sort of vegetative polypus, every inch of it being capable of developing a growing bud. The horse-radish is thus of very easy culture, but to be grown to perfection requires a deep soil. It is ordinarily grown in an out-of-way shaded corner, and left without care, furnishing in this way an ample supply of roots. Serious accidents have happened from aconite roots being used instead of horse-

Horse-radish. Aconite.

radish, and therefore great caution is required. With the view of supplying instruction on this point, and preventing future accidents, specimens of the two roots have of late years been placed side by side in the botanical museums of Kew and Edinburgh, and above we represent the roots

of both, by which, it will be seen, that they are quite different.

Beet-root.—Of beet there are two reputed species in cultivation—namely, the root-beets (*Beta vulgaris*) and the leaf-beets (*Beta cicla*), to which may be added the sea-beet (*Beta maritima*). Of root-beets there are many varieties, but only those having dark-coloured flesh are deemed garden vegetables in this country. Of these the principal are Belvoir Castle, Cattell's dwarf purple top, mulberry, Nutting's dwarf red, Henderson's pine apple, Sang's blood red, Williams' superb crimson, and Dell's dark crimson, the last being also useful for flower-garden decoration, from the beautiful metallic-like lustre of its deep purple leaves. To grow these well, the ground ought to be light and well pulverised, for the spindle-root will be diverted if it meet with obstacles, and become forked and distorted. Trench the plot to the depth of eighteen inches, removing large stones, roots, and hard clods of earth; lay a stratum of manure at the bottom of the trench, in order to attract the root downward; then return the fine earth. Let the work be completed before frosts set in, and at the middle or end of March the seeds are to be sown in drills 1½ to 2 inches deep, dropping them two or three inches asunder. Cover with light fine earth, and tread or beat the covering earth with the spade. If the plants rise equally, thin them gradually, till they stand from nine to twelve inches apart every way, or even fifteen inches for the large-growing sorts. Beet will transplant, but the operation dwarfs the plants, and at best it is attended with some risk. Keep the rows or beds entirely free from weeds by hand-weeding or hoeing. Some roots will be ready in September, and thence throughout winter. In using them, or prior to storing up during winter, cut off the straggling leaves, being careful not to wound the roots; they keep well in dry sand, but become tainted if wet straw or decomposable vegetable substances are placed in contact with them.

The Onion Tribe.

This savoury class of kitchen vegetables comprises the onion, leek, garlic, and shallot, the former two being by far the most important. All are natives of eastern countries; but they grow to great perfection in the British Islands.

The Onion.—For a crop of onions the soil should be rich, light, deep, and well exposed to the sun. Before sowing, work and enrich the bed to the depth of eighteen inches. Sow the seeds either broadcast or in shallow drills any time in March, or even so late as the beginning of April. Cover with fine sandy earth, and roll the surface even. As the onions advance, thin them out two to four inches apart, according to the variety. Keep the ground quite free from weeds. In September, twist the necks, take up the crop when the leaves become yellow, and expose the onions to sun and air under a shed till they be externally quite dry. Sow again in the first or second week of August 'winter onions,' for using in the following spring and early summer. The kinds are: Blood red, Danver's yellow, Deptford, Globe, Giant Rocca, James' long-keeping, Nuneham Park, Queen, Tripoli, White Lisbon, and White Spanish.

The potato-onion is very valuable on account of the heavy crop it produces. The tree-onion is also no less useful than curious. These are propagated by bulbs, as is also the Italian pearl-onion—a very distinct flat-leaved species—which produces clusters of pearl-like bulbs, varying in size from that of small peas to small marbles, and is invaluable for pickling.

The Leek, if properly treated in a favourable soil and situation, grows to a very large size. It is a plant which is much improved by proper transplantation, but yet can be grown very well in its seed-bed. The Musselburgh leek, with its improved sub-varieties, Ayton Castle and Henry's Prize, is the best; but the London Flag is still a favourite with some growers. Sow the seeds in shallow drills at the close of February or early in March, and cover them with half an inch of fine soil; as the plants grow, keep the surface clear of weeds by hand-picking and passing the Dutch hoe lightly on each side of the leeks. Presuming that they are thinned out at first to stand three inches asunder, half of the plants will remain, and the other half will be removed to another situation. Thus the plants in the seed-bed will stand six inches asunder, and will be greatly assisted if the ground be opened on each side of them at the distance of nine inches, and manured spit-deep. A crop of fine middle-sized leeks will thus be obtained in the succeeding autumn.

To transplant leeks, prepare the ground at the end of June, or early in July, by digging and manuring the soil richly to the depth of a foot or fifteen inches. Mark off the lines at widths of nine to twelve inches, and make holes along them six inches deep and as far apart. Collect a number of the strongest leeks, trim off the straggling roots, and all the suckers or offsets. Drop a small handful of powdery manure, or reduced year-old cow-dung, into each hole, place in it a leek, and holding it by one hand, fill the hole with water. The object is to fix the leek as in a case, to which it can adapt itself, and which it will fully occupy, becoming, under propitious circumstances, a plant of large size and of most excellent quality.

Garlic, one of the most pungent species of *Allium*, is increased by dividing the bulbs into cloves or smaller bulbs, and planting them in good sandy loam at any period between the middle of February and the end of April. Draw drills two inches deep, and ten inches apart, then press the root-end of each clove firmly into the earth till it stand erect; let the distance between each be six inches, and fill up the drills with fine sand. Keep the ground free from weeds, and when the leaves turn yellow—which usually happens about the end of July or the beginning of August—take up the bulbs with a trowel or handfork, and keep them in a dry room.

The Shallot is a native of Palestine; its culture may be the same as that of garlic, but some prefer making three to four inch deep drills, and filling them with rich soil, upon the top of which the bulbs are set, and a little mound raised on each side to support them till they become firmly rooted. This is then removed by a hoe, and by pouring water from the rose of a watering-pot, till the bulb stand wholly out of the ground. Thus they become mere surface bulbs, supported entirely by the fibrous roots, which pass deeply beneath

into the rich soil. Shallots have a strong but not unpleasant odour, and are therefore generally preferred to the onion for various purposes of cookery, and for making high-flavoured soups and gravies.

The Chive, one of the smallest of the garlic tribe, is a hardy and useful vegetable, its leaves being superior, in the estimation of many, to young immature onions for using in early spring. The plant grows in tufts somewhat like small rushes in appearance, but of a colour resembling the deep green of young onions. It is readily increased by dividing the roots in April or early in May.

Salads.

Salads are those plants whose fresh leaves are eaten at table raw, or only dressed with zests and condiments without the preparation of cooking. The principal vegetable of this kind is

The Lettuce, of which there are several varieties, but all may be classed under two heads—the upright or cos lettuces, and the cabbage-lettuces, for using in summer and autumn. The following are among the best kinds: Alexandra white, Giant white, Holme Park, London white, Paris green, Paris white, and Sugar-loaf cos; All the Year Round, Brown Genoa, Grand Admiral, Drumhead, Ne Plus Ultra, Royal Albert, and Victoria cabbage-lettuces. Sow in very shallow drills of fresh-digged ground, made rich with rotten manure. Strike the drills a foot asunder, and as the plants rise, thin them first to two inches, then, for table use as small salad, to six inches, and for the larger sorts, finally to one foot. With care they may, in moist weather, be safely transplanted during spring and summer. Spring and summer lettuces are sown in about monthly succession from February to July. Some lettuces heart freely; those which do not, should be assisted by passing a string of bast round them from the middle upwards. This bandage must not remain many days, otherwise the plant will run to seed, and become bitter.

In August and September sow, for use in winter and early spring, hardy sorts, such as Brown Dutch, Hammersmith hardy green, and Stanstead Park cabbage; hardy winter white, Lee's Nonpareil, and Williams' Victoria cos. When the plants are three inches high, thin out half of them, and transplant some into warm quarters, and others under a frame; protect by coverings of hoop and mats those in the open ground; and if they bear the winter, thin the plants early in the spring to six inches apart. The plants in the frame will rarely fail if the earth be free from slugs.

Endive is a salad of a pleasant bitter taste. There are six principal sorts in ordinary cultivation—the Batavian green and white, curled green and white, Moss or Stag's Horn, and Williams' Gloria Mundi. The seeds are sown at different periods between the beginning of June and the second week of August, as required for the autumnal, winter, and spring crops. When the plants are three or four inches high, they may be removed to beds of moderately enriched loam, to stand a foot apart. But transplantation is not essential, for very fine plants are produced in the seed-beds. When they are nearly full grown, they must be prepared for the table by blanching, as otherwise they would be too bitter for use.

Blanching may be effected by several methods; the most simple is that of passing a string of soft bast matting round the leaves of each plant, so as to exclude the light from the heart; but as hard frost is very injurious, some plants ought to be removed to a bed of dryish earth or sand under an airy shed; or a garden-frame, partially covered, might be placed over a certain number of those already tied up. Common six to eight inch flower-pots, turned upside down, and a piece of slate laid over their hole; or conical 'endive' pots, may be used for blanching individual plants. The curled endives do best when blanched without tying. The Batavian endive, however, requires a bandage at all times, otherwise the central heart, which alone is edible, will never be rendered tender and white.

Chicory, and that too common weed, the *Dandelion*, when blanched, form excellent winter salads, allied in flavour to endives. The former should be sown in June, and thinned out to about six inches apart. And the roots of both may be transferred in succession to beds or boxes of earth, where they are excluded from light; and with little more than an ordinary cellar temperature, continuous supplies can be easily grown.

Garden-cress.—In alluding to the culture of this common salad, we will include the *white mustard*, because they naturally are companions, and are often grown together. In cultivating mustard and cress, it is essential only to remark, that the latter should be sown three or four days in advance of the former, because cress is more tardy than mustard. Both are very accommodating herbs, inasmuch as they will grow upon wetted flannel in a saucer placed in any apartment, as well as on the floor of a green-house. On shipboard, under cover, they can thus be obtained throughout the winter; and in the garden from March to November, by successional sowings made once every fortnight. Sow either broadcast over the surface of a fresh-digged bed, raking and patting in the seeds by the flat of the spade, or in shallow drills half an inch deep, covering the seeds with a little fine soil. Sow thickly; and if the young plants rise, as they are apt to do, with a covering or cake of earth over them, remove it by means of a light branch-whisk. Mustard should be taken before the rough leaves be fully developed, a precaution which is too often neglected. The kinds of garden-cress usually grown are the curled, triple-curled, and broad-leaved; but the golden cress, or Australian cress, as it is often mistakenly called, is by many deemed preferable to either, and its leaves are best when the plants stand from one to two inches apart.

Water-cress, a native plant, is grown to most advantage in, and by the edges of spring rivulets and running streams.

Celery is a native of Britain, found in ditches and marshes near the sea. The odour of the wild plant is very rank and disagreeable, and its juice is acrid and dangerous. By cultivation, this dangerous weed has been brought to the condition of that highly esteemed vegetable called garden celery. Of this there are many varieties — the common upright hollow white celery; the purple-stalked; the giant white and red; solid; Goodall's White; Sandringham White, &c. Celery may be sown in a frame, with gentle heat, at the end of February, for the first crop, and thence to the end of May, on a warm sheltered border for succession.

All the seedling plants should be pricked out into intermediate beds of soft rich earth—the first sowings over a gentle hotbed—to bring strong transplants in June and July.

Self-sown seed, which falls from a seeding plant in October, if it light on rich earth, will bring noble plants in the spring, fit to go at once into trenches.

Prepare the ground for celery by previously manuring and trenching the whole plot to a depth of from 18 to 24 inches; and after the ground has settled, dig a trench or two a moderate spade's depth, depositing the earth on a ridge to the right and left of the trench. Clear the bottom, lay on it three inches of leafy manure, and re-dig the ground, to incorporate it with the manure. Then select a number of the best plants, trim off loose straggling fibres, and all the side-suckers, but do not touch a true leaf: set the plants four or five inches, and the large sorts six inches, asunder, and fill the holes with water; shade during sunshine for three days, and give water every evening, unless there be copious showers.

As to future attention, water the plants frequently in the evenings till they begin to grow; and when they become three inches higher, stretch a line along each edge of the trench, and cut down by the spade as much soil as will suffice to earth the stems to that height; break it fine, and grasping each plant firmly in the left hand, insinuate the soft soil around it; then place a little finely reduced manure along the channel of the trench on each side, remote from the stems; this will nourish the fibres, without coming into contact with the leaves; water poured once or twice along the course of this manure will promote its action. Repeat the earthings as often as the plants advance three inches, and manure the extreme edges where the spade has made a groove, till at length the trenches become level with the surface of the ground. Then dig out soil, and add it, sloping ridgewise till the plants are 'landed' up fifteen, eighteen, or more inches above the surface-level. Celery may be preserved from frost by boards placed over the leaves. Some perform the earthing up by one or two operations when the plants are nearly full grown, but although this is less troublesome or expensive, the crop is less crisp and tender.

Celeriac, or turnip-rooted celery, is raised and nursed in the same way as celery; but in planting out, the ground is dug and enriched, not trenched, and the plants are set by the dibble or garden trowel along the course of shallow drills drawn by the hoe, six inches apart, watering them freely. As the growth advances, bring earth to the plants, by which the knobby roots will be blanched and made delicate and tender. When these are the size of small turnips, they are fit for the table. Celeriac is never eaten raw as common celery, but is boiled, and served up with melted butter.

Salad Flowers.—Raw salads are very much improved in appearance by being dressed, or mixed with edible flowers; of these the many varieties of nasturtium or Indian cress are the most easily attained throughout summer and autumn; next the beautiful blue and white flowers of borage; and in early spring the pretty white and pink bells of the wood-sorrel can be gathered abundantly in most thickets and woodlands; the petals of the common dandelion, clipped small, and spread over, impart a rich gold-dust-like appearance; and the blue flowers of endive and chicory treated in like manner are also productive of pleasing effect.

Sweet Herbs.

Rosemary and *Lavender* are hardy under-shrubs, natives of the south of Europe. They yield powerful essential oils when distilled with water, that of lavender being employed, as are also the dried flowers, in the preparation of *lavender-water*. Bees are extremely partial to the flowers of rosemary. Both these plants are propagated with great facility by slips of the young side-shoots, trimmed of their ragged bark, and merely dibbled into the soil. They will grow almost anywhere, and in any aspect; but the flowers possess the highest degree of fragrance when the plants grow in a dry, sandy, or gravelly earth with sunny exposures. Spring or September is most favourable for propagation by slips.

Common and *Lemon Thyme* are used in seasonings; both are raised from seeds sown early in spring. Or by opening the earth around the stems, spreading the reclining shoots, and strewing some fresh sandy mould over them; roots are soon formed, and thus a supply of young plants is obtained. It appears essential to renew thyme, and to place it—lemon-thyme particularly—in new soil, otherwise the plants dwindle and perish. A dry and rather poor soil seems most favourable to the growth and fragrance of thyme.

Sage, red and green, is propagated in the same way as lavender.

Of Marjoram there are three sorts—*pot marjoram*, *sweet* or *knotted marjoram*, and *winter marjoram*—which grow readily in a dry light soil, but require change of situation. The first and third sorts may be propagated by division, but the sweet marjoram should be raised from seeds sown in April every year, the plants to be thinned out to the distance of six inches.

Savory.—Winter savory is propagated either by slips and cuttings, by separating the lower shoots, or rooted offsets, in spring; summer savory is an annual, sown in April, and becoming fit for gathering in the summer and autumn.

Mint.—Spear or garden mint, and peppermint, are not properly sweet herbs; the latter, indeed, is only used medicinally, the essential oil possessing pungent qualities. Spear or garden mint is used in the kitchen for a variety of purposes familiarly known. All the species, including *pennyroyal*, another medicinal mint, are cultivated by division of the roots in spring. Mint delights in moisture, and extends with great rapidity. Care, however, is required to give it a new situation when the plant becomes weak, and its leaves appear of a pale and yellowish hue.

Fennel, of which there are two kinds, the green and reddish leaved, is used for sauce and garnishing for salmon. It is a hardy perennial, prefers a dryish rich soil, and half-a-dozen plants are sufficient for most establishments.

Tarragon is a perennial herb, used as a condiment in raw salads, as also for making Tarragon vinegar; it is propagated by division, and prefers a light, rich soil with a warm exposure.

To dry and preserve these herbs, select the

shoots just as the flowers form and shew colour, but before they expand; suspend them in an airy situation, under cover, not exposed to the sun.

Miscellaneous Vegetables.

Artichoke.—The globe, and the oval-headed, are the only two varieties usually cultivated. The plant has fibrous, rather fleshy roots, large deeply cut leaves, whitish with down, and it produces an upright stem, bearing at the summit an oval or roundish flower-head, not unlike a gigantic thistle. Artichokes can be raised from seed, but much more speedily by offset-suckers, which are produced freely by the parent plant. Select a spot of open ground; any soil will do, but a free light loam is to be preferred. Trench and manure it well to a depth of two feet, so that it may keep in heart during many years. The work ought to be performed before frost sets in; and if the soil be heavy, it will be prudent to set it up in ridges. Suckers are generally ready in April. Having procured the desired number, level the ground, dig a portion of it again, and reduce the surface to the finest condition possible; then, after trimming off decayed leaves and damaged roots, plant the suckers in a row, two feet asunder. It is usual to form a complete bed of three or more rows, five feet apart; but some think that artichokes and other permanent vegetables ought to be set in single rows ten feet apart, so that the ground between them can be cropped with annual vegetables, which will benefit the artichoke, by the rich manure applied at the first and other successional croppings. A dozen good plants will be sufficient for a moderate family; but as some suckers may fail, it will be prudent to set the plants one foot asunder, securing the roots firmly in the soil, and giving a copious watering at the time of planting; the supernumeraries can be removed when all are safe.

The subsequent culture is as follows: Hoe occasionally, to destroy weeds and keep the surface open. If little heads be pushed up the first year, remove them as soon as seen. When the plants become torpid and yellow in autumn, a few of the outside leaves are to be pulled off by the hand; the ground should then be marked by the line on each side at eighteen inches' distance from the plants; and being cut straight by driving the spade to its full depth along the line, the earth is to be dug up, broken fine, and laid on the surface of the eighteen inches left on each side of the plants, bringing it carefully against them, so as not to fall into their hearts, but yet to protect them effectually: the operation is called *landing up*. This done, fill the trenches with stable litter, straw, dung, or fern; and in the event of hard frost, bring more litter close to the plants, and lay it over the *landing* earth, for artichokes are rather tender, and may be destroyed during severe winters. This practice is to be observed every year, with the additional precaution to cut the flower-stems close down.

Spring-dressing consists in removing suckers after levelling the earth, and digging in a little of the short manure that is left on the ground after clearing away the straw, &c. and making the soil neat. One or two of the strongest suckers may be left on each stock.

Asparagus is justly esteemed one of the choicest vegetables of the garden. It is a native of the southern British and other European coasts, and is perfectly hardy, so much so as to resist a frost below zero; it nevertheless benefits by protection and generous culture.

Towards the end of March, place the line along the course of the bed; strike two drills with the hoe at sixteen inches apart, and two inches deep; or in the broad beds make similar drills nine inches asunder; and in both scatter the seeds pretty thickly, say half an inch apart; cover with fine earth, and pat it to a smooth surface with the spade. Watch the coming up of the plants, and be prepared to dust them with air-slaked lime, if slugs threaten them. When they shall have fairly formed rows of young seedlings six inches high, thin out the plants to three or four inches apart for after-transplanting. The *seed-rows*, for forcing, thin first to three, and afterwards to five inches, and then leave both to grow, observing to use the hoe repeatedly, to keep down weeds.

In forming new plantations, it is customary to use two-year-old plants. April is the best season for planting. Let the ground be prepared before frost sets in by deep trenching and rich manuring; but by all means adopt the practice recommended by Grayson, who produced what he styled *giant asparagus* about the year 1830. We give his own concise directions in the following quotation: 'If your ground be stiff and unpleasant to work, get some milder earth to mix with it, and a very large cart-load of rotten dung to about every ten square feet; trench it two spit deep, and loosen the bottom; let the dung and earth be well mixed together. When your land is fit for planting, draw your drills six inches deep, and sixteen inches from the first row to the second—that will form a bed—and ten inches between each plant in the row. Do not raise your beds till they have been planted one year; then put on about four inches of mould out of the alleys, and cut till the 10th of May. If you keep them well manured, they will last twenty years; but *never cut later than the 4th of June*. Let them be eight feet in the clear from bed to bed, so that you may crop between, and lose no land.'

In future treatment, when the stems become yellow, cut them down at two inches above the soil; clear the surface with hoe and rake, and lay on the beds eight inches of decayed leaves, with a sprinkling of salt, guano, or other saline manures; but when sea-weed can be got, it is preferable to decayed leaves; and salt may be dispensed with. These annual enrichments, be it observed, might be persisted in with every bed that is used for cutting; but for the beds devoted to raising plants for forcing, it will suffice to make the ground thoroughly rich at the time of trenching; because the plants, when three or four years old, will be removed to the forcing department; yet a coating of half-decayed leaves or manure, after the stalks are cleared off, will not be lost, as the stronger the plants, the more remunerative will be the produce.

In cutting the young tops it must not be forgotten that if every shoot be taken off a crown, to the end of a long season, that root will be destroyed. To prevent the crowns from being too deeply buried, in consequence of the autumnal dressings, it is customary to fork the beds late in March, digging them carefully, or rather loosening the surface with a fork of three prongs, and taking the rough earth

into the alleys; this operation also gives freedom to the plant by opening the soil.

With respect to forcing, it is very easy with narrow distant beds to bring the plants somewhat more forward in the spring, by digging trenches eighteen inches wide, or wider, and above a foot deep, and filling them with warm stable-dung, blended with a third part of forest-tree leaves, raising the dung to six inches above the surface-level. The gentle warmth communicated will stimulate vegetation, and it would be assisted by covering the beds with hoops and mats, or with boards set up ridgewise, in the event of sharp frosty nights; but forcing is more easily done by removing the roots with their adhering earth, and packing them closely together among good soil over warm manure in hotbeds; or in fire-heated hot-houses. Successional forcing-beds are prepared as soon as the cutting of the earlier begins to decline, or even when it is at its height.

The Cucumber and *Melon* are somewhat delicate in growth, and require a fine climate and extremely rich soil. The cucumber is usually grown over a heap of old horse-dung, on a spot of ground open to the south, and large enough to permit a two or three light frame to rest upon it. Dig out the soil a foot in depth, and lay it on one side, or around the trench. If this soil be a light friable loam, incorporate it, a month before it is to be used, with one-third part of leaf or vegetable earth and old decayed dung, and again dig this mixed earth two or three times. But if the soil produced from four or five year old couch-grass roots, harrowed from a field of sound loam, can be procured, it is the best aliment for the cucumber. The soil should be ready in April, and the work of planting begun in the first week of May, by filling the excavation with stable manure to the height of a foot above the surface-level of the unmoved earth, and placing on it the frame and lights. In a week, the manure will have settled, and is then to be covered with a six-inch layer of soil, and a hill of dryish earth, raised a few inches higher, under each light, in which eight or ten seeds of any approved variety may be sown. If preferred, the seeds may be prepared by previous sowing, in pots in a slight hotbed, and the plants so raised can be transferred to the hills. But as the plan now recommended is not one of forcing, it is safer to begin on the spot by sowing seed and covering the bed with the lights, and those with mats or boards every night.

As the plants rise, observe them carefully, and pick out the central buds when the rough leaves have become strong. 'When the plants shoot forth after a second stopping above the second joint of the laterals, produced by the first, they seldom miss to shew fruit at every joint, and also a tendril, and between this tendril and the shewing fruit, there may be clearly seen the rudiment of another shoot. This shoot is then in embryo, but if developed, it becomes a fruitful lateral. And when the leading shoot has extended itself fairly past the shewing fruit, then with the finger and thumb pinch it and the tendril off just before the shewing fruit, being careful that, in pinching off the tendril and the shoot, the shewing fruit be not injured. This stopping of the leading shoot stops the juices of the plant, and enables the next shoot—the rudiment above mentioned—to push vigorously, and the fruit thereby also receives benefit.' (M'Phail.) These remarks will also apply to the melon, which, however, requires more heat and more careful attention.

Whether cucumber and melon plants have been raised separately in pots, or from seeds sown in the frame, they ought to be progressing early in June, and should be stopped occasionally, till fruit begin to shew itself. The soil must never be *wet*, but always retained in a free and rather moist condition with water heated to the temperature of the frame. No water ought to be poured against the stems—it should be applied to the soil around the slope of the hills only. Air ought to be admitted on all warm days, by tilting the back of the lights till three o'clock; but after that hour, the frame should be kept closed. As long as the nights are cold, cover with mats, and boards over them, at sunset. Every decayed leaf and weak shoot should be removed as soon as perceived.

In order to raise and fruit cucumbers or melons before midsummer, *forcing* must be employed. The hotbeds of the best regulated gardens are conducted without masses of manure under the roots; heat is obtained by means of hot-water tanks; thus manure is economised. By this method, cucumbers and melons can be produced during the spring and summer months with certainty and precision.

Nasturtium, or Indian cress (*Tropæolum majus*), is a native of South America. Although chiefly grown as a hardy ornamental annual, the flowers afford ornamental garnishing of salads, and the green seeds, picked off when nearly full-grown, are used as a pickle. Any one who once possesses a few varieties with choice coloured flowers, can annually reproduce them, by sowing seed in any way or place which may suit his taste. These may be sown from the middle of March to the middle of May.

Parsley.—Several kinds of parsley are in cultivation; these are the plain, curled, triple-curled leaved, and the broad-leaved Hamburg parsley. The first is hardiest, and is indispensable in cold districts, where large supplies are wanted in winter and early spring; but otherwise, preference ought to be given to the curled-leaved kinds. The last has large fusiform or slender carrot-like roots, which are served at table as a separate dish, or used for flavouring soups, &c. and its leaves are used as those of the other kinds. This vegetable is one of the most easily cultivated. It is sown in drills—generally in March—in any spare patches of border, lies long in the ground before springing, and arrives at maturity the next season. When it has attained this state, it may be cut when required; even during a long winter-storm, if the precaution has been taken to cover a drill or two with peas-stakes or other close wattling. Any plants that shew a disposition to run to seed, should be pulled out, and the crop may be allowed to stand for two years. When really fine leaves are wanted, transplant the finest curled-leaved plants, when they have three or four leaves, into rich soil, at distances of eight to twelve inches apart.

Rhubarb is propagated by suckers from a division of old plants, set at three to four feet apart, the ground being previously well manured and trenched to a depth of at least two feet. When once planted, it requires no

trouble, but keeps growing till the plants run up to seed. To give additional size to the leaves, cut off the seed-stalks. In taking away the leaf-stalks for use, do not cut them, but wrench them from the main stock, so as to take them out by the socket. The variety called Victoria Rhubarb is the one generally cultivated by growers for market; but the following, and especially the first four, possess much more delicacy of flavour: Stot's Monarch, Scottish Champion, St Martin's, Nonpareil, Linnæus, Prince Albert, New Crimson, and Scarlet Defiance. Rhubarb may be forced by very simple means. A common method is to cover it in the early part of the winter with a box, surrounded with tree leaves or stable manure. This blanches as well as brings forward the stalks. Some force rhubarb in darkened forcing-houses, or cellars; and we have known farmers have it at Christmas, and onwards through the winter, by growing it on temporary deal boards suspended under the roofs of their feeding-byres. For forcing, plants at least two years old are most suitable; and outdoor plants should be allowed to retain all their leaves for at least the first year after planting. Watering copiously is necessary in the early stages of growth, whether in the open air or under boxes. A well-planted plot of rhubarb will continue productive for seven or eight years.

Sea-kale is a perennial vegetable, deriving its name from being found growing in a wild state on the sandy coasts of Europe, including those of England. The method of garden culture is as follows: the ground should be trenched and prepared as for asparagus; and at any dry period of March, when the surface-earth will work freely, drills should be drawn by the line, two inches deep, and the seeds scattered along them, or five or six seeds should be inserted at distances of two feet apart. The seeds are then covered with earth, and when the plants become strong, they are to be thinned of supernumeraries, leaving one or two of the strongest remaining, eighteen inches or two feet asunder every way. If the plants are weak, it will be prudent to retain double the number. During the first season, nothing more will be required than to keep the bed or row free of weeds. In the following spring, if the plants stand nearer to each other than eighteen inches, the surplus number should be carefully raised, and transferred to another prepared space, planting the crowns of the roots two inches below the surface, and eighteen inches to two feet apart. Or thickish pieces of the old roots cut in lengths of two to three inches may be planted. In either case the first crop may be taken the second year after sowing or planting; and the plantation will remain productive for many years.

Sea-kale may be forced at various periods, commencing with November, by inverting large pots over the plants, and covering those with warm dung, or dung and leaves, to excite and maintain a heat in the pot and soil of about 55° Fahrenheit. Or this may be done by removing its roots to a forcing-house, as recommended for rhubarb. Thus sea-kale is at command from December to March by heat, and then the succession can be maintained during April and part of May out of doors by covering up the crowns with inverted pots, having a little earth laid around to keep them in place and exclude light. Straw in contact with any blanched plants is unsuitable, as it communicates a bad flavour. Where the plant grows wild, by sea-shores, it is gathered in the finest condition when whitened by the sand, which the wind piles gently over its head in the manner of a snow-wreath.

Spinach is an annual of which there are three principal kinds: the round-leaved or smooth-seeded, which, as well as the next, is sown chiefly for spring and summer crops; broad-leaved Flanders; and the triangular-leaved, prickly-seeded, or winter spinach. The first two should be sown about the end of January, and again in February and March, for successive spring and summer crops, in drills twelve to fifteen inches apart, or between rows of peas and beans, as the crop will be removed before these require the full space. The triangular-leaved is to be sown at the end of July and in August for coming into use at the beginning of winter and in early spring; the plants require thinning and hoeing. The outer leaves only are to be taken during winter and spring, the inner leaves forming in their turn an ample succession. Spinach may be raised in any common garden soil; but the more that soil has been previously enriched with dung the better; and for either winter or summer spinach it is hardly possible to manure the ground too highly, as succulency adds greatly to the value of this vegetable. Liquid manure proves effective. Always select an open situation, not too near low-spreading trees, &c.; as in close and shady places it is mostly drawn up weak, and soon runs to seed, without attaining perfection. A kind of wild-spinach is not uncommon in Britain (*Chenopodium Bonus-Henricus*); but it is inferior in succulency, and more bitter than the garden sort, which, however, in the estimation of many, is surpassed by the young shoots of the common nettle, that in early spring abound under hedges, in old pastures, and waste places.

Leaf or Spinach Beets (*Beta cicla* and *B. maritima*).—Of the first there are three varieties with plain leaves—namely, white, red, and yellow, each of which has a sub-variety with curled or crisped leaves. Their cultivation is the same as recommended for *beet-root*, page 554. All are distinguished by the brilliant colours and large size of their leaf-stems; which, besides insuring for them prominent positions in the flower-garden, and even in window-pots, are used in autumn and early winter, cooked in the manner of sea-kale. The leaves of their young thinnings, as well as those of the other garden and field beets, form agreeable substitutes for the common spinach in summer; and their very early as well as abundant spring growth of young leaves specially recommends them to cottagers, for use at a period when green vegetables are scarcest. For spring use the plain-leaved white is preferred, from being considered hardier than the others; and it should be sown in the last week of July or first of August, the plants being thinned afterwards to only about three or four inches apart. The *Sea-beet* (*B. maritima*) is noted by our oldest horticultural authors as an excellent substitute for spinach, and might with but little cultural care be grown largely on sea-coasts that now produce little.

Vegetable marrow is a species of gourd (*Cucurbita*), the pulp of which, from its richness and flavour, has been called *marrow*. Its leading

varieties are the common long white, and yellow; Custard, and Moor's Vegetable Cream.

Sow in pots of any light soil early in April, treating the plants exactly as cucumbers under glass. About the middle of May, transfer them to a bed of rich earth over a trench filled with warm stable-dung. Protect the plants by a hand-glass or frame, which, if the shoots are to run on the ground, should be raised by four or more bricks, giving air freely. When danger of frost ceases, remove the light or frame.

Mushrooms are not propagated from seeds, for they have no observable seeds, but by spawn, or portions of their substance, mingled in what are sold under the name of mushroom spawn bricks. About Michaelmas is the general season for making mushroom-beds, though this may be done all the year round. A quantity of horse-droppings should be collected, and thrown together in a heap to ferment and acquire heat; and as this heat generally proves too violent at first, it should, previously to making the bed, be reduced to a proper temperature by frequently turning it in the course of a fortnight or three weeks, during which time, should it be showery weather, the heap will require some sort of temporary protection, by covering it with litter or such-like, as too much wet would soon deaden its fermenting quality. The like caution should be attended to in making the bed, and after finishing it. As soon as it is observed that the fiery heat and rank steam of the dung are gone off, a dry and sheltered spot of ground should be chosen on which to make the bed. The place being determined on, a space should be marked out five feet broad, and the length—running north and south—should be according to the quantity of mushrooms likely to be required. If for a moderate family, a bed twelve or fourteen feet long will produce a good supply of mushrooms for some months, provided proper attention be paid to the covering.

'On the space marked for the bed, a trench should be thrown out, about six inches deep; the mould may be laid regularly at the side, and if good, it will do for earthing the bed hereafter; that of a more loamy than sandy nature being best. In the trench there should be laid about four inches of good horse-dung, not too short, for forming the bottom of the bed; then lay on the prepared droppings a few inches thick regularly over the surface, beating it as regularly down with the fork; continue thus, gradually drawing in the sides to the height of five feet, until it narrows to the top like the ridge of a house. In that state it may remain for ten days or a fortnight, during which time the heat should be examined towards the middle of the bed, by thrusting some small sharp sticks down in three or four places; and when found of a gentle heat the bed may be spawned, for which purpose the spawn bricks should be broken regularly into pieces about an inch and a half or two inches square, beginning within six inches from the end of the bed, and in lines about eight inches apart. After spawning the bed, if it is found to be in that regular state of heat before mentioned, it may be earthed, thus: the surface being levelled with the back of the spade, there should be laid on two inches of mould, which is then to be beaten closely together, and when the whole is finished, the bed must be covered about a foot thick with good oat-straw, over which should be laid mats, for the double purpose of keeping the bed dry and of securing the covering from being blown off. In the course of two or three days, the bed should be examined; and if it is considered that the heat is likely to increase, the covering must be diminished for a few days, which is better than taking it entirely off. In about a month or five weeks mushrooms will most likely make their appearance, and in the course of eight-and-forty hours afterwards they will have grown to a sufficient size for use; when instead of cutting them off close to the ground, they should be drawn out with a gentle twist—the cavity being then filled up with a little fine mould, gently pressed in level with the bed.'

The method above described is intended for open-air culture; but in large gardens, a mushroom-house is usually chosen, the beds being formed in large shallow boxes, arranged in the manner of shelves around the walls. Light is not required; and mushrooms may be abundantly produced in a dark cellar or outhouse, provided suitable materials are obtained, and care bestowed in regulating the temperature at about 55° to 60°, and maintaining a moist atmosphere.

HORTICULTURAL MONTHLY CALENDAR.

Having in almost every instance mentioned the seasons for sowing, planting, transplanting, and otherwise attending to the culture of vegetables in the kitchen-garden, it would only be waste of room to repeat directions, as is usually done, in connection with the different months. It is hoped, therefore, that the following general references to the months will be sufficient:

January.—Trench and delve up all open grounds, if the weather permit; and in warm exposures, sow early peas and other articles that are to be brought forward early.

February.—Continue turning up the ground designed for early crops; plant early potatoes, sowing may go on a little more briskly, especially in warm and well-sheltered borders.

March.—This is a particularly busy month, being, from its open and drying character, favourable for all works of preparation. Peas, beans, asparagus, onions, carrots, &c. are sown; and various articles are transplanted from frames.

April.—A continuance of preparing, sowing, and planting; hoeing, thinning, and clearing out of weeds require also to be attended to. In very dry weather, seedling-beds should be carefully watered.

May.—The main crops are now to be sown, early peas earthed up and staked, and young plants transplanted.

June.—Sow kidney-beans, runners, &c.; water growing plants, if required; hoe potatoes, cabbages, and peas; and thin out beds. Gather medicinal and sweet herbs, when in bloom, and dry in the shade for winter use.

July.—Sow broccoli for the last time; also turnips, lettuces, &c.; and prepare all the unoccupied plots of ground for autumn and winter crops.

August.—Commence now to sow for the crops of next year, such as onions, early cabbages, and parsley; also winter spinach. Earth celery; hoe and thin turnips; cut down stems of gathered artichokes, and generally clear out all stumps and stalks of used plants, for their continuance exhausts the ground to no proper purpose. Cut herbs and gather all bulbous crops, such as onions, as soon as they are withered in the stem.

September.—The kitchen-gardener has now got his principal labours in cropping over, and his chief work is continuing to sow for winter and spring successions; he also digs potatoes that seem ready, and takes care to cut down and clear off weeds.

October.—The garden having been prepared for spring vegetables, sow what was left over last month, including celery, asparagus, also early peas and beans. The cabbages and savoys require to be earthed up as high as the leaves. Remove carrots and other roots, and store them away for winter use.

November.—If temperate and open, sowing of peas and beans may be continued in sheltered borders.

December.—During the latter end of November, and the open period of this month, the chief operations are digging, manuring, or trenching vacant ground, and attending to the preparation of composts. In frost, the labour exerted on the plants need only be protective; and the gardener usually occupies much of this period in pruning his trees, wheeling in and storing dung, and attending to the more delicate plants in frames and sheltered borders. In mild weather, a few early peas and radishes may be sown in dry warm borders, and small salads and cucumbers in hotbeds.

Royal Water-lily (*Victoria regia*).

THE FLOWER-GARDEN.

FLOWERS have in all ages been cultivated by persons of leisure and taste, for the beauty and variety of their forms, colours, and fragrance. While generally healthful and exhilarating, from being pursued in the open air, flower-culture is justly reckoned a pure and harmless recreation, which, by leading to the tranquil contemplation of natural beauty, and diverting the mind from gross worldly occupations, has a positively moral, and therefore highly beneficial tendency. Flower-gardening affords the ready means of studying vegetable forms, which, were they to be sought in the fields and woods, would necessitate a course of botanical study which few artists have the leisure or inclination to adopt. It has also the advantage of being alike open to the pursuit of high and low, the peasant and the peer, the over-toiled man of business and the industrious artisan. It may be followed with equal enjoyment by both sexes, and, as is well known, on every imaginable scale, from that of a single flower-pot or tiny front-plot, to the princely conservatory and exquisitely varied parterre.

The natural grace, simplicity, and attractive colouring of flowers have afforded endless themes to moralists and poets; and volumes have been penned to shew how many associations of feeling, simple and sublime, these beauteous objects are calculated to excite. On this field we cannot afford to expatiate, and therefore proceed at once to the more practical object of shewing how the lovers of flowers may rear them for themselves.

MODES OF LAYING OUT FLOWER-GARDENS—FRONT-PLOTS—BOWERS.

Flowers are cultivated in the borders and parterres of gardens of a mixed kind along with kitchen vegetables and fruits; and this may be said to be the general plan in those grounds of limited space belonging to persons of moderate means. Many, however, cultivate flowers in 'flower-gardens' exclusively appropriated to them, and also in isolated clumps for the decoration of lawns. The method of culture is the same in all cases, and therefore it is unnecessary to enter into particulars with reference to the various sizes and kinds of gardens in which flowers may be grown.

The directions given in the previous sheet on the laying out, shelter, and exposure of kitchen-gardens, apply also to flower-gardens. The soil should be rich and dry, the exposure full and uninterrupted towards the sun, so that a free air may play over the ground; and means should be at hand for providing needful supplies of water.

If the garden is seen from a parlour-window, as is often the case, the plan most agreeable is to lay out the foreground as a patch of well-shaven grass, which is fresh both winter and summer; on its further side there may be a semicircular

border; then a walk; and next parterres of such form and size as will suit the extent of the ground. If the garden contain kitchen vegetables, they should be out of sight of the windows of the dwelling-house, or at least not brought ostentatiously forward. 'It is more difficult,' says the author of the *Florist's Manual*, 'than may at first appear, to plan, even upon a small scale, such a piece of ground; nor, perhaps, would any but an experienced scientific eye be aware of the difficulties to be encountered in the disposal of a few shaped borders interspersed with turf. The nicety consists in arranging the different parts so as to form a connected glow of colour; to effect which, it will be necessary to place the borders in such a manner that, when viewed from the windows of the house, or from the principal entrance into the garden, one border shall not intercept the beauties of another; nor, in avoiding that error, produce one still greater—that of vacancies betwixt the borders—forming small avenues, by which the whole is separated into broken parts, and the general effect lost. Another point to be attended to is, the just proportion of green turf, which, without nice observation, will be too much or too little for the colour with which it is blended; and, lastly, the breadth of the flower-borders should not be greater than what will place the plants within reach of the gardener's arm without the necessity of treading upon the soil, the mark of footsteps being a deformity wherever it appears among flowers.'

Whether all the flowers of a kind—such, for instance, as violets, hyacinths, &c.—should be cultivated together in beds, or interspersed and mingled with others, is a matter for taste to decide. Dr Neill judiciously observed, on the choice of flowers for borders: 'The plants are arranged in mingled flower-borders, partly according to their size, and partly according to their colour. The tallest are planted in the back part, those of middling size occupy the centre, and those of humble growth are placed in front. The beauty of a flower-border, when in bloom, depends very much on the tasteful disposition of the plants in regard to colour. By intermingling plants which grow in succession, the beauty of the border may be prolonged. In a botanic garden, the same plant cannot be repeated in the same border; but in the common flower-garden, a plant, if deemed ornamental, may be often repeated with the best effect; nothing can be finer, for example, than to see many plants of double scarlet lychnis, double sweet-william, or double purple jacobæa.' The practice of growing flowers in beds of one kind has of late years, however, become very prevalent, and has this advantage, that it gives bolder masses of colour, and enables the florist to cultivate in the open ground, and with the best effect, many tender plants that would be lost in a mixed border.

The Dutch, who are among the best flower-gardeners in the world, have lately begun to copy the English in ornamenting turf-lawns with plots of various kinds of flowers; but in all their large and regular gardens, they still dispose each kind of flowers by themselves. 'We ridicule this plan,' says Hogg, in his *Treatise on Flowers*, 'because it exhibits too great a sameness and formality; like a nosegay that is composed of one sort of flowers only, however sweet and beautiful they may be, they lose the power to please, because they want variety. It must undoubtedly be acknowledged that a parterre, no matter in what form—whether circular or square, elliptical or oblong—where all the shrubs, plants, and flowers in it, like the flowers in a tastefully arranged bouquet, are variously disposed in neat and regulated order, is a delightful spectacle, and worthy of general imitation. Yet still, in some particular cases, I am disposed to copy the Dutchman; and I would have my bed of hyacinths distinct, my anemones, my ranunculuses, my pinks, my carnations distinct, and even my beds of hollyhocks, double blue violets, and dwarf larkspurs distinct, to say nothing of different sorts of roses. Independently of the less trouble you have in cultivating them when kept separate, you have beauty in masses, and you have likewise their fragrance and perfume so concentrated, that they are not lost in air, but powerfully inhaled when you approach them.'

As to front-plots in towns and suburbs, if they be limited to a few square yards, it will be better not to attempt the growth of flowers at all, but to lay them down in greensward, if it will grow, or clean gravel, with perhaps a selection of the finer varieties of ivy, jasmines, and cotoniasters on the side-walls or railings; and elsewhere a variegated holly, box-tree, laurel, aucuba, sweet-brier, rose, or some other hardy shrub, to enliven them. Nothing, however, can be more wretched than a few sickly plants struggling for a miserable existence amid the dust and smoke of a town; and a person of good taste will never attempt the growth of flowers unless he can command the requisite amount of air and sunshine. In laying out little front-plots of this description, circular, oval, oblong, and other simple forms should be preferred; for nothing looks more ridiculous than the imitation of labyrinths and intricate designs on so small a scale. A few plain forms, in keeping with the front of the building and size of the plot, may produce elegance; but intricate divisions, with lines of gravel between, scarcely broad enough for a human foot, are toyish and trifling in the extreme.

An error not uncommon in deciding what flowers shall be planted, is to select numbers merely for their rarity or novelty, without reference to what will be their appearance when in bloom. Unless for botanical illustration, make a choice of flowers on three principles—those that will thrive in the situations assigned to them; those which will be beautiful when in bloom or leaf, although common; and those which will bloom or produce effective foliage at the particular seasons required, to insure a succession of varied beauty throughout the year.

Bowers and rustic seats often form a pleasant feature in connection with the flower-garden. The forms of these are so numerous, that there is ample scope for choice; but there is one mode of forming a bower so natural in character, as to be deserving of special notice—that of cutting over old hard-wood trees at suitable heights for sitting upon, and allowing their young coppice shoots to grow up around, as illustrated by the accompanying sketches. Fig. 1 shews the stump of a tree, with the young branches growing up round it; and fig. 2 illustrates the fashion in which these branches may be made to form an elegant canopy;

the branches being simply tied together by means of wire; and if a few plants of ivy, choice climbing-roses, honeysuckles, or clematises are planted

Fig. 1.—Tree-stump preparing for a Bower.

around the base, the whole will soon become very compact and beautiful. The wires should not be

Fig. 2.—The same, more advanced.

tied tightly, lest they cut the branches in the course of time; and perhaps, for this reason, ordinary string-ties would be preferable.

CHARACTER AND TREATMENT OF FLOWERS.

The design of the flower-gardener is less to produce size and strength in his plants, than to cause them effectually to bloom. It is proper, then, to mention, that whatever tends to give excessive vigour to the stems, will prevent the formation of flower-buds. Thus a too rich and moist soil, or recent manure, is injurious.

Flowering-plants are usually classified under *Annuals*, *Biennials*, and *Perennials;* but floriculturists usually separate the last into *Herbaceous* and *Ligneous* or woody plants, and add another division under the name of *Bedding-out plants. Annuals* generally require to be sown annually, as they live and bloom only one season; but some kinds are capable of being perpetuated by cuttings. *Biennials,* in general, do not blossom till the second season after sowing, and then die or become much deteriorated. They are produced by seed, but some of the finest double varieties are continued by cuttings. *Perennials* continue for many seasons to grow and blossom annually; those termed *herbaceous* having stems which grow up, bloom, and fade every year; while those termed *ligneous* comprise both shrubs and trees. A *deciduous* plant is one which sheds its leaves every autumn, and reproduces them in spring. An *evergreen* retains its leaves in permanent succession, the old ones never falling off till after one or more years.

The prevailing colours of flowers are yellow, orange, white, pink, scarlet, red, blue, purple; only few are blackish, and many are variegated, or composed of different tints. Proper culture, pure air and sunshine, increase the brilliancy of the tints, and give massiveness to the corollas. Plants of kindred species may likewise be improved by hybridising or crossing, the general principle of which is the artificial application of the pollen of one plant to the stigma of another, by which means some of the most beautiful flowers have been originated. The changes effected on the daisy, the rose, and the violet, occur as striking instances of metamorphoses induced by selection, crossing, and culture. Speaking of the laws by which a change of colour is produced, Dr Lindley observes: 'A blue flower will change to white or red, but not to bright-yellow; a bright-yellow flower will become white or red, but never blue. Thus the hyacinth, of which the primitive colour is blue, produces abundance of white and red varieties, but nothing that can be compared to bright-yellow; the yellow hyacinths, as they are called, being a sort of pale yellow-ochre colour, verging to green. Again, the ranunculus, which is originally of an intense yellow, sports into scarlet, red, purple, and almost any colour but blue. White flowers, which have a tendency to produce red, will never sport to blue, although they will to yellow—the rose, for example, and the chrysanthemum. It is also probable that white flowers, with a tendency to produce blue, will not vary to yellow; but of this I have no instance at hand.'

PROPAGATION.

Seed.—In sowing seeds, it is of the utmost importance to regulate the depth of their covering according to their size. Thus, while peas and beans may be buried to a depth of three or four inches, very minute seeds, such as those of lobelias and tobacco, should be thinly covered, or merely scattered over the surface, and the soil kept moist till the young roots have taken secure hold.

Dividing the Root.—This is one of the most simple methods of propagation. The root of the growing plant is partially uncovered, and one or more portions are removed; the root is then covered up, and the detached parts transplanted in soft earth prepared to receive them. Nine-tenths of herbaceous perennials may be treated in this way.

Suckers.—These are young shoots thrown up from the roots of the main plant, round which they cluster. They may be removed in winter or spring by taking up with a part of the root attached, and immediately planting out. If any flower-buds appear on them, take them off, so as to give strength to the leaf and root-developing powers to the plant.

Layers.—Some plants send out layers or runners along the ground; these have joints at certain points, which have a tendency to take root. Nothing is more easy than to propagate by causing the layers of some plants to take root; but there is a little more care required with others, such as the carnation, the young side-shoots of which, called *grass*, are selected for layering. These are stripped of their lower leaves, and the stem is cut half through by an oblique slit near the base; it is then fixed to the ground with a hooked stick or peg, and is covered slightly with mould, giving a little moisture. Roots will in general strike out in a few weeks; and at the end of the season, the plant is ready for being cut from its parent and transplanted.

Pipings.—Propagation by piping is an expeditious mode of raising young plants. 'Take off the upper and young part of each shoot close below a joint, with a sharp knife, cutting each off at the third joint, or little knob; and then cut the top leaves down pretty short, and take off the lower and discoloured ones. When you plant the pipings, let the earth be light and sandy, and recently loosened; dibble no hole, but gently thrust each piping half-way down into the soft earth, and fix it in the bed. Water them often, if the weather is dry, but moderately, just to keep them moist; and shade them from the hot sun in the day. If pipings are covered with a hand-glass, they root sooner than those which are exposed. Piping is done in June and July; and the plants will be well rooted and fit to plant out in October.'

Cuttings are strong shoots cut from the parent stem or branch, and set in the ground. The cutting should be cut off slantingly and smoothly; and the soil requires to be dry, or not too moist. Roses and honeysuckles are among the shrubby plants usually propagated by cuttings; and familiar examples of more succulent ones are seen in geraniums, verbenas, petunias, fuchsias, calceolarias, &c.

Grafting is a mode of propagation occasionally adopted with roses and some other flowering-plants, but it is more applicable to the FRUIT-GARDEN, which see.

Budding, a method of propagation specially applicable to rose-bushes, consists in inserting the fresh-cut bud beneath the bark of another plant. The leaf on the selected bud is to be taken off, for if it remained it would exhaust the sap, and the bud would in all likelihood wither and die. Along with the bud, a small slip of bark is to be

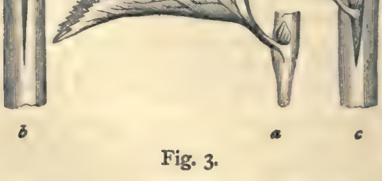


Fig. 3.

taken; and if this bark separate freely, it is a test of there being sap enough to form a union. The slip of bark is to be inserted beneath the bark of the other plant, in a slit made for the purpose, and the whole tied with a strip of mat or thick worsted, soft cotton twist, &c. to keep out the air. The preceding cut represents the various parts in budding: *a* is the bud cut out, with a shield of bark attached to it; *b*, the stem, with a slit in the bark to receive the shield attached to the bud; *c*, the bud inserted, and the leaf cut away.

SELECT FLOWERS FOR THE GARDEN.

Flowering plants are now so numerous, both as respects species and varieties, that a bare list of them would more than fill the present sheet. All, therefore, that can be reasonably expected from us is a few hints as to those which are most approved, and cultivated chiefly in the open air. A person with little experience should stock his garden only by degrees—adding a small number of different sorts every year, according to fancy, and what he finds to be the capabilities of the soil and exposure. In commencing to make a choice for a moderately sized garden, or for still smaller plots of ground and borders, we should also recommend the plan of cultivating a mixed variety of different colours and different heights—those which are smallest being in front, and nearest the eye, and the other rows rising in height and massiveness as they recede. With as few as four colours, four sizes, and six different periods of coming into bloom, a mingled border may be established with ninety-six sorts, which will present a pleasing assemblage to the eye.

ANNUALS.

Some annuals are *hardy*, and others *half-hardy*. The hardy kinds will grow and blossom in open borders, without artificial heat or protection; those which are half-hardy will also grow in the open air, but are improved by being brought forward under hand-glasses. Of the delicate class of annuals which must be constantly kept under glass, it is not our purpose to speak. The greater number of annuals may be sown in the month of April. The soil should be fine, and have a warm exposure. If the weather be dry, irrigate with pure soft water occasionally.

Among the vast number of annuals that offer themselves to the choice of the gardener, the following may be mentioned as taking the lead in the *half-hardy kinds:* African marigold, French marigold, China aster, marvel of Peru, Indian pink, convolvulus, amaranthus, zinnia, ten-week stocks, &c. *Hardy kinds:* Adonis, candytuft, larkspur, lupines, sunflower, lavatera, poppy, nasturtium, sweet pea, Venus's looking-glass, Virginian stock, mignonette, purple jacobæa, Clarkias, Collinsias, Nemophilas, Helichrysums and other 'everlastings,' several kinds of ornamental grasses, &c.

If annuals are required on a more extended scale, the best plan is to leave the selection to a respectable nurseryman, or get his descriptive list of their height, colour, &c. to choose from.

Whether tender or hardy, all annuals should be carefully trimmed, and kept from straggling. Some will require thinning. Remove withered and imperfect blooms, and clear off all plants that are finished flowering, and shewing a 'seedy,' unsightly appearance.

BIENNIALS.

Among the so-called biennial plants suitable for ordinary flower-gardens are included the following, each having several varieties: Canterbury bells, carnation, pink, hollyhock, sweet-william, wallflower, Lavatera arborea, purple digitalis, and the biennial races of stock gillyflower. Some of these are very beautiful, and none more so than carnations.

The *Carnation.*—There are many varieties of the carnation, but all those acknowledged as 'florists' flowers' are arranged in three classes—flakes, bizarres, and picotees. Flake carnations possess but two colours, with large stripes through the petals. Bizarres have three shades of colour, also in stripes. Picotees have a white or yellow ground, marked on the margins with purple or some other colour. Besides these, there are 'cloves' and other self or one coloured kinds, which are indispensable for the abundance and fragrance of their flowers; while another tribe, called tree carnations, are grown in hot-houses for flowering in winter. Show-flowers of the carnation should be at least three inches in diameter, with the edges of the petals waving or smooth, not serrated. The petals must fill the calyx, but not to bursting. Whatever colours the flowers may be possessed of, they should be perfectly distinct, and disposed in long regular stripes, broadest at the edge of the lamina, and gradually becoming narrower as they approach the claw of the petal. Each petal should have a due proportion of white or yellow ground, one half, or nearly so, which should be perfectly clear, and free from spots.

The best soil for carnations is good, strongish loam, enriched with well-rotted stable-dung, and quickened with a little sand or old lime mortar. The quantity of manure can only be determined by the previous condition of the ground: if made too rich, the flowers will lose their fine colours; if left too poor, they will want vigour. Let the ground be prepared before winter with dung, and a rough furrow laid up to the frost. In April, give a fresh digging, and plant in rows three feet by two. This width is to make room for layers, without which a fine blow of carnations cannot be maintained above one year. As the plants shoot up, they must be tied to neat rods. Select sorts are propagated by layers, as before described, but seeds selected off good sorts should be sown annually. The young layered plants will be ready for removal by the end of autumn, when they may be set in flower-pots if the soil is too damp, and apt to cause rotting in winter; but if sufficiently dry, the layers may remain till spring, and it will be of use before winter to earth them up, sloping and beating the mould about them so as to throw off the rain.

The *Hollyhock*, with good soil, shelter, and proper exposure, will attain a height of twelve or fourteen feet, but generally reaches seven or eight, and is very suitable to ornament fronts of cottages, edgings to shrubberies, or the centre of clumps in lawns. The colours are very various; as pink, dark purple, yellow, &c.—the double sorts being the richest and most esteemed. The seeds of hollyhocks are sown in May; and in September or October the young plants are transplanted into the ground where they are intended to blossom; but improved varieties require to be propagated by cuttings. Although classed as biennials, the plants will spring and bloom for a number of years.

Pinks require similar treatment with the carnation, only, instead of laying, the less tedious modes of piping and cuttings are suitable for their cultivation.

Sweet-william.—Of this prettiest and most varied of summer flowers, there are the double and single flowered, of both of which the varieties are innumerable. The first are propagated by cuttings, or by laying the flowerless shoots; and the latter by seeds, which should be saved only from the finest varieties, having large, smooth-edged, finely and distinctly coloured blooms.

Wallflower.—The double-flowering varieties of this fragrant plant are mostly perpetuated by cuttings, although some 'German' sorts come true from seed. The single kinds form the best plants when grown from seed, which should be saved from plants selected for the approved colour, size, and form of their flowers.

Brompton, *Cape*, and other biennial *stocks.*—These showiest of a gay and fragrant tribe should be sown in May or June; transplanted into beds 4 to 6 inches apart, when they are 3 to 4 inches high; and again, where they are finally to bloom in August and September, unless in cold districts in which they are unlikely to stand the winter, where they should be wintered under glass, and planted out in early spring.

PERENNIALS—BULBS.

Under this head may be included the hyacinth, narcissus, iris, lily, tulip, gladiolus, Ixia, snowdrop, crocus, scilla, and others.

The *Hyacinth* has numerous varieties, differing in colour—as blue, red, and white. A rich, sandy soil and saline atmosphere, with a warm exposure, are favourable in developing its properties. In the British Islands, the hyacinth will endure the winter in the ground, and is among the earliest blossoming plants of spring. In Holland, the bulbs are lifted and carefully stored during winter. The grower who desires to meet with success, must obtain an annual supply of Dutch bulbs, which are to be had from the seedsmen. The domestic culture of this flower will be alluded to under another head.

Of the *Narcissus* there are many species and varieties, which include daffodils, white narcissus, jonquils, and polyanthus narcissus, forming a most showy race of spring flowers. Most daffodils have a lightish-yellow flower, with a deeper yellow cup. Jonquils are deep yellow. Of the polyanthus tribe, distinguished by their many flower-heads, there are sulphur-coloured, single and double, white, &c. Like hyacinths, the bulbs may remain in the ground during winter.

Of the *Iris* there are various sorts, all of them beautiful from the rich diversity of their colours. The Persian iris is low, with delicate blue and violet blossoms; the Chalcedonian is taller, and distinguished by the great size and magnificence of its flower, which is a purple-blue striped with white; the Spanish, by the number and diversity of its varieties; and the English, by more robust growth, larger, and scarcely less diversified flowers. All like open, warm exposure; the varieties of the

latter prefer substantial, rich soil, and the others such as are of a more sandy description.

The *Lily* is the most showy genus of hardy bulbous plants, as well as the most varied in size, colours, and times of flowering. Of its many species, the orange, scarlet, white, tiger, and turn-capes, are old flower-border favourites; but all are surpassed by the recently introduced *Lilium auratum*, and other Japanese kinds, which are found to be most valuable acquisitions, whether treated as greenhouse or as hardy herbaceous plants. *Lilium giganteum* is also a very distinct and striking addition from India.

The *Tulip* is the pride of the bulb-garden in spring and early summer, or at least stands pre-eminent in general estimation. Like many other bulbs, it is a native of the Levant, and was brought to its perfection in Holland, where tulip-fancying was at one period a mania. The finest tulip-gardens are at Haarlem, which has a warm and saline climate, with a light and rich soil. Round the roots and over the beds, sand is freely scattered, so that the tulips seem as if growing from a sandy beach. In this country, follow the same practice. Plant in October, or early in November. In forming a bed of tulips, the bulbs should be set at a distance of seven inches apart, and in straight rows, taking care to arrange the different colours tastefully. To raise from seed, or to improve the varieties by crossing, is a work of time, and not to be thought of in ordinary circumstances. The following is Hogg's criterion of a fine variegated late tulip: 'The stem should be strong, elastic, and erect, and about thirty inches above the surface of the bed. The flower should be large, and composed of six petals: these should proceed a little horizontally at first, and then turn upwards, forming almost a perfect cup with a round bottom, rather widest at the top. The three exterior petals should be rather larger than the three interior ones, and broader at their base: all the petals should have perfectly entire edges, free from notch or serrature; the top of each should be broad and well rounded; the ground colour of the flower, at the bottom of the cup, should be clear white or yellow; and the various rich-coloured stripes, which are the principal ornament of a fine tulip, should be regular, bold, and distinct on the margin, and terminate in fine broken points, elegantly feathered or pencilled. The centre of each petal should contain one or more bold blotches or stripes, intermixed with small portions of the original or breeder colour, abruptly broken into many irregular obtuse points. Some florists are of opinion that the central stripes or blotches do not contribute to the beauty and elegance of the tulip, unless confined to a narrow stripe exactly down the centre, and that they should be perfectly free from any remains of the original or breeder colour. It is certain that such appear very beautiful and delicate, especially when they have a regular narrow feathering at the edge; but the greatest connoisseurs in this flower unanimously agree that it denotes superior merit when the tulip abounds with rich colouring, distributed in a distinct and regular manner throughout the flower, except in the bottom of the cup, which should be a clear bright white or yellow, free from stain or tinge, in order to constitute a perfect flower.'

In order to have tulips in anything like perfection, they require great care. As strong sunshine injures them, they must be covered with a slight awning from the sun's rays. They must also on no account be allowed to go to seed, for in that case the bulb is exhausted; to prevent which, they should be watched when they approach perfection, and the head and stalk cut off. A usual signal for cutting is when they cease closing at sunset, or when the edges of the petals exhibit the slightest appearance of withering. They should be cut rather too early than too late. After cutting, admit the sun to the stems; and when these wither, which may be in June or July, lift the bulbs, and lay them aside in a dry airy situation; there let them remain till the period for planting before mentioned.

The *Gladiolus*, a showy tribe, originated from several species, natives of the Cape of Good Hope, which, although of very recent introduction among florists' flowers, now occupies even a more distinguished position among late summer and early autumn flowers, than the tulip does among those of spring and the first weeks of summer. The named varieties are counted by hundreds, which are annually added to by dozens of deserving new kinds. They succeed best in rich soils of moderate texture, where neither exposed to excessive drought nor scorching sunshine. The best time for planting is about the end of March or beginning of April, and the smaller bulbs should be placed about three inches under the surface, allowing a little more for those of larger sizes. They should be taken up as soon as the stems and leaves become withered, and after being dried in moderately aired, cool vineries, or other convenient places, stored away among dry sand, where safe from frost, till the return of planting-time. Most of the varieties may be grown successfully in pots, among rich, lightish compost, and plunged among sand or ashes, either under glass or in open beds, till they commence flowering, when they may be taken for the decoration of the conservatory, greenhouse, or window-plant stands.

Ixias are a numerous tribe of dwarfish, yet elegant growing Cape bulbs, remarkable for the beauty and great diversity of their colours; and although formerly deemed greenhouse plants, many of the kinds stand permanently in the open ground if planted in well-drained, light, rich soil, at a depth of about four inches, and covered as well as surrounded with sand. In frosty weather, cover with dry litter, straw, or fern-fronds, held in place neatly by mats, nets, or cords.

The *Crocus* and the *Snowdrop* are two small bulbous plants, so well known for their hardy growth that little need be said of them. Crocuses are very various in colour—blue, yellow, white, and so forth; and the principal thing in planting is to dispose these colours in a pleasing variety. Crocuses, like other bulbs, require occasional transplanting: this may be done in October. Of the snowdrop, there is a double-flowered variety; and another species, the Crimean (*Galanthus plicatus*), which, although long known to bulb-fanciers, was brought into more general notice during the Russian war.

Scillas, or *Squills*, are another race of pretty spring flowers, in which the richest blue colours prevail, varied, however, in some of the kinds with different shades of red and white. Dog's-tooth violets are a small family of pretty bulbous

flowers, esteemed for their beautifully spotted and blotched foliage, as well as for the elegant forms of their red, pink, white, and party-coloured blooms. Nor should the Tiger-flowers of Mexico (*Tigridia pavonia* and *T. conchiflora*) be omitted; for, although not sufficiently hardy to remain in the open ground throughout the winter, they succeed under the same treatment as the gladiolus, and are unsurpassed for the beautiful markings of their richly coloured, but short-lived, abundantly produced flowers.

PERENNIALS—TUBERS.

In this group, the *Dahlia* (named from Dahl, a Swedish botanist) deserves the first place, both from its beauty and size. It is a native of the temperate plains of South America, and requires a dry and airy situation for its growth. The plants should have a free space of from two to three feet all round. The stems, at and near the top of which are the rose-like blossoms, rise to a height of two to five feet or more, and require to be supported by stakes. New varieties are raised from seeds, and good sorts are perpetuated by separating a part of the root to which a bud or young stem is attached. Frost at once blights the green stalks; and when these seem utterly withered and dried, carefully lift the tubers, and place them in a dry situation for the winter. In April, or early in May, they must be sprung in moderate heat under glass, and then planted out, and occasionally watered. Dahlias are now found of almost every shade of colour, except blue, every year adding its novelty.

The *Peony*, with roots somewhat resembling those of the dahlia, is one of the oldest and showiest herbaceous plants of May; splendid varieties are now cultivated, all of which may be propagated by division of their roots or tubers, and thrive in ordinary garden soils.

The *Ranunculus* is a stock beauty in all gardens, and it has some hundreds of varieties. The tubers are small. The blossom resembles a compact small rose of a flattish form. Plant when the weather is mild and dry, from the middle of October till the end of February, in lightish rich soil.

Anemones, both *double* and *single*, in endless variety of colours, have long been deemed flower-garden associates of the ranunculus, requiring similar cultivation, and a little more care in shading the more brilliant-coloured varieties from bright sunshine.

FIBROUS-ROOTED PERENNIALS.

The genera, species, and varieties of flowering plants with fibrous roots are very numerous. Among a few of those most prized, let us take first the humble *Daisy* (day's-eye), which originated in that 'wee, modest, crimson-tipped flower,' the wild *gowan*, or daisy, that is now found in many varieties—the mottled, crimson, white, and pink being the more common. There are also variegated-leaved varieties with double white, red, and single flowers; all may be propagated to any extent by simple separation of the roots.

Dielytra.—The Chinese Dielytras, of three sorts, suited either to the greenhouse or open air, are among the most elegant recent introductions. Several allied plants, including the Fumitories, are also well worthy of cultivation in the borders.

The *Primrose* family includes several pretty flowering plants. The true primrose and its varieties, as early spring-flowers, succeed those of the crocus in giving colour to the borders. The highest cultivated of the race is the *Polyanthus*, which sends up stems loaded at top with a bunch of flowers. The colour most admired is that shaded with a light and dark rich crimson, resembling velvet, relieved by a bright golden hue. The *Auricula* (*Primula auricula*) flourishes best in rich soil from old turf and rotted cow-dung. Its chief colours are red, pink, crimson, purple, apple-green, and mulberry. On the leaves, as well as petals of some, there is a fine meal, which is injured and marked by drops of rain or artificial irrigation; and therefore flower-fanciers take care to shelter the plants with frames, and allow no drops from the watering-pot to touch them. When treated with attention, a bed of auriculas may be rendered very beautiful. The *Japanese Primrose*, of which there are already a number of varieties, is a recent and highly promising introduction, which has been found quite hardy; and is of robust growth, having its showy flowers in several successive whorls or heads, upon a common stem.

The *Campanula*, or pyramidal bell-flower, in its different varieties, blue and white, is a graceful flower, with pendent bells, which should be found in all tastefully laid-out borders. It may be kept long in flower, by cutting off the blooms as soon as they begin to wither.

Pansy.—By the French, the cultivated violet or heart's-ease is called *pensée* (thought); hence our name pansy. This is essentially the florist-flower of the cottager, surpassing all others in the lengthened continuance, as well as in the endless diversity in the colouring of its blooms. No flower in the garden has lately engaged so much attention as this; by means of culture, crossing, and hybridising, it has attained great perfection as respects size, form, and richness of colour. 'The most approved method of propagation is by taking off young slips in the autumn, which is the best time, as then the ground and weather are most suitable for the formation of rootlets, on account of its dampness and dullness; [but the season for striking cuttings will depend upon the time when they are wanted to flower]. A bed is prepared of light but rich soil, raised a little above the path, in order to drain off all superfluous moisture. The cuttings are then made ready, by stripping them of their under-leaves, and cutting close below the bottom joint, from which the roots must spring; for if this is not done, the cutting will decay to that joint, which frequently destroys the whole. After the bed is prepared, the cuttings are arranged according to their varieties, each sort being marked by a tally-stick, numbered or named according to the pleasure of the owner. The cuttings will be well rooted in about six weeks, when they may be planted out for blooming in the spring, or potted to keep over winter in a frame. The soil in which the pansy is found to flourish best is a compost of cow-dung one-half, fresh loam one-quarter part, leaf-mould one-eighth part, and coarse sand one-eighth; but peat-soil should on no account be intermixed. These ingredients should be well mingled together, and purified from worms and slugs by having lime-water frequently thrown

over the heap, and in a short time it will be fit for use. The situation best adapted for the heart's-ease is one which is sheltered from the mid-day sun, but which receives a little in the morning and evening when it is not so powerful as to injure the colours. Transplanting may be performed at any season, but in doing so an error is prevalent. We see the plants taken up with a ball of earth around them, and planted again with it. Now, as everything deteriorates the soil in which it grows, and as the pansy entirely pierces every particle of earth its roots can reach, therefore that which we take up with it must be entirely exhausted. When replanted, the pansy can receive very little food from its new situation, as its roots do not by nature straggle far from the stem. To prevent this starvation, it is much better to shake away most of the soil, and replant with its roots unconfined.' Cultivators recognise three distinct races of pansies—namely, selfs, fancies, and bedding-out or edging kinds, for the favourites in each of which, growers must have recourse to the annual catalogues issued by plant-dealers.

The *Pyrethrum* is a hardy tribe of florists' flowers recently introduced, and rivalling the well-known China aster in the size, form, and colour of its flowers. It is propagated by division, and thrives in ordinary garden soil. All the kinds flower most profusely in summer; but a considerable number of the newer kinds bloom again in the autumn.

The *Phlox* comprises a very numerous race, which generally bloom in the later summer and autumn months; when they have few equals in the flower-border for showy elegances, and variety of colours, from the purest white to the deepest purple or crimson. All are easily propagated by either cuttings or division, and they succeed in any fertile soil of ordinary texture.

The *Pentstemon*, although strictly sub-shrubby, is usually included among herbaceous plants; and its many varieties harmonise well with those of the phlox, their propagation being also similar.

SHRUBS—CLIMBERS—EVERGREENS, &C.

Among these, the *Rose* unquestionably deserves the first place, having from time immemorial been a favourite in every garden. There are some hundreds of species and varieties of roses; among which are included China-roses, hardy climbing-roses, moss-roses, Scotch roses, hybrid perpetual roses, &c. The China-rose is delicate, with few petals in the flower, and yields a succession of blossoms through a great part of the year. The moss and cabbage roses are old favourites that will never be discarded; but modern taste is chiefly directed to the 'hybrid perpetuals' and tea-scented China-roses; while in shrubberies and hedges the sweet-brier is entitled to prominence from the delicious odour of its leaves, and should have a place in every garden. All kinds of rose-bushes are exhaustive of the soil, and should be frequently manured, if not transplanted to fresh mould. In order to keep the 'perpetuals' in bloom, cut off all blossoms which seem about to wither.

For adorning the walls of summer-houses, cottages, &c. the *Honeysuckle* excels, and should, both for its beauty and fragrance, by all means have a place in every garden, however humble. The common and Chinese winter-flowering *jasmines* are tall running shrubs growing up in numerous branches, which, being well covered with small, narrow leaves, and a profusion of flowers, are very suitable for leading up to verandahs or concealing pieces of wall. The *clematis* has recently obtained a prominent place among florist climbers; many of its varieties being unsurpassed for the gay and long-continued profusion of their flowers, which vary in colour from pure white to deep purple or mauve, and in size from three to nearly ten inches in diameter.

Among the various tall bushy deciduous shrubs most appropriate as an ornamental background in gardens, are the different kinds of hawthorns, azaleas, viburnums, Wegelias, and lilacs. Few out-of-door exotic shrubs surpass in beauty the red, white, and yellow flowering currants, several of the raspberry family, especially the *Rubus diliciosus* of the Rocky Mountains, and the white-barked Himalayan *R. biflorus*.

Evergreens, with the exception of rhododendrons, hardy heaths, and their allies, constitute a class of shrubby plants more suitable for the ornamental front-plots of dwelling-houses, or for approaches and lawns, than for ordinary flower-gardens; because, although the green of the leaves is pleasing in winter, when other vegetation is dead, these plants are very exhaustive of the soil, often prevent the sun from getting to the borders, and keep the ground in a litter with fallen leaves at a time when trimness is expected. Those that are most generally esteemed for ornamental plots, or other limited situations, are the innumerable modern varieties of the rhododendron, the various tribes of *Laurels*, *Alaternus*, *Arborvitæ*, *Holly*, *Juniper*, *Mahonia*, *Box*, *Laurustine*, *Ivy*, and other coniferæ, &c. The *Laurustine* yields a plenteous and early supply of blossoms. The *Arbutus* is a beautiful shrub, highly suitable as an embellishment in lawns; it has small, greenish, bell-shaped flowers, and yields a strawberry-like fruit in early winter. *Ivy*, the most pertinacious of climbing-plants, will grow almost anywhere, and requires but little attention in either pruning or training; many beautifully variegated-leaved and other varieties have recently been introduced, some of which form admirable house or window plants even in densely populated towns.

With proper care, evergreens may be most successfully lifted and transplanted either about the beginning of September or May. The plan is to dig all round them, at a distance equal to the compass of the branches, sinking the trench to a point beneath the sole of the plant; then lift them bodily with the whole mass or ball of earth round the roots. A pit must be prepared for the reception of the ball, and when placed in its new situation, fill in the rest of the pit with fine earth, laying the rootlets straight, and packing in all neatly to the surface. A copious stream of water must now be poured from a watering-pot upon the newly placed mould, round the stem; this carries the particles of earth to the rootlets, surrounding each with its proper nourishment, and giving solidity to the whole. If likely to be exposed to winds, the plant should be supported till thoroughly rooted in its new abode. (See ARBORICULTURE.)

SUCCESSION OF BLOOM.

The directions given in the foregoing pages, and in the floricultural calendar appended, it is hoped, will assist in leading to an arrangement whereby a constant succession of blossom may be obtained, for on this much depends. As a further aid, we offer the following hints, furnished by a correspondent to the *Gardeners' Chronicle:* 'Supposing equal skill in the cultivation of plants in general to exist among gardeners, the great superiority in effect of one garden beyond another consists in the distribution and arrangement of the plants themselves, so that a succession of blossom and a due contrast of colour should, where practicable, keep every border furnished even to the end of autumn. In this respect, most gardens are deficient. Succession is not attended to, except for the more limited space and favoured spots near the mansion, or in front of the conservatory. In most gardens it is considered sufficient to keep any border where plants have blossomed free from weeds and neatly raked. To the mind of the gardener, this border tells its own history, of the beauty of which he had boasted but a few weeks since; but the visitor or casual observer who walks through the garden, only seeking to please his eye with varied gaiety, makes no allowance for the past which he has not seen, and remarks, that though some parts are beautiful, a great portion of the ground has nothing worth looking at.

'By the subjoined method, the comparative gaiety of the scene may be kept up, and a relief to the eye, not without interest to the observer, preserved. Mix the seeds of the following well-known annuals:

Mignonette.	Heart's-ease.
Carnation poppy.	Clarkia pulchella.
Papaver amœnum.	" alba.
Dwarf Dutch poppy.	Godetia of all sorts.
French poppy.	Antirrhinum majus.
Branching larkspur.	" sparteum.
Eschocholtzia Californica.	" versicolor.
" crocea.	Collinsia bicolor.
Campanula speculum.	Coreopsis tinctoria.
Candytuft, varieties.	Convolvulus minor.
Nasturtium.	Gilia tricolor, and other species.
Centaurea Cyanus, various.	

Then let this mixture of seed be very thinly scattered upon the borders early in the spring; it need not interfere with any ordinary work on the borders that may be required afterwards, and in places where the ground may be disturbed, many of the seeds will only appear at a subsequent period, and consequently flower later in the autumn. Most of these annuals will continue flowering until the frost kills them, and if not removed too soon, will leave behind them sufficient seed for years to come. Every gardener has remarked the strength, the beauty, and the effect of single plants of self-sown annuals that spring up occasionally in a flower-border, and have escaped that destruction which the merciless hoe, in the hand of the undiscriminating labourer, inevitably entails upon them.

'One case yet remains of much consequence to present as well as to future effect, though generally but little attended to: this is the frequent examination of all annuals as they expand their first flowers, and the pulling them up, unless in habit, form, and colour they are fit to remain for stock. Crowded as annuals generally are in the patches sown in gardens, their true character and beauty are seldom seen; and if, among the mass sown, some few blossoms appear more striking than the rest, and the seed of these is considered more worthy of preservation, it is generally too late to take away the worthless without destroying the plants most desired; and the seed so saved from the most select variety is but little better than that from any of the other plants.

'The system now recommended gives the advantage of separation and a power of selection, with the certainty that a selected plant will, by its position as a single plant, not only blossom in beauty and vigour, but afford that abundant harvest of good seed which will amply repay in future years the trifling care thus proposed to be bestowed upon it.'

PLANTS FOR THE GREENHOUSE, AND FOR WINDOWS, &C.

These are of various kinds, both herbaceous and shrubby, and require to be distinguished from the preceding, because they are exotics, too delicate for open-air exposure in all weathers, and require to be kept in a temperature above the freezing-point. This is done by placing them in a greenhouse or conservatory heated slightly in winter by means of flues or pipes of hot water. The most approved situation of a greenhouse, of the old lean-to form, is against a wall with a southern exposure; and, if possible, placed in connection with a range of artificial vineries or hothouses. In many instances, a conservatory is connected in a very agreeable way with the parlour of a dwelling-house, by which its beauties are enjoyed without the trouble of going out in bad weather or during the inclemency of winter. Except a few prominent specimens planted in the beds or borders, all the plants are in pots; and whenever it can be done without risk of injury, the sashes are opened, and free exposure permitted. At the country seats of various English noblemen, as well as in public gardens, such as those at Kew and Edinburgh, conservatories are formed on a magnificent scale, so as to allow the free growth of even tall trees, such as the palm and other large tropical plants.

The most beautiful greenhouse flowers usually cultivated are camellias, geraniums, fuchsias, orchids, cacti, and azaleas. The camellia is a woody shrub, yielding splendid rose-like flowers of colours varying from white to red. The geranium is a well-known exotic, with clustering bunches of flowers of different colours, or with beautifully variegated and tinted foliage. The fuchsia, introduced from Chili, is a handsome shrub, of different varieties, yielding exceedingly beautiful flowers, varying from pure white to bright crimson; and the manner in which these flowers depend from the branches, like drops of ladies' ear-rings, has a singularly graceful effect. The cacti are interesting exotics, distinguishable by their thick and succulent leaves, on which usually grow small and sharp prickles; the flowers are splendid. Besides these, we may enumerate, either for their great beauty of blossom or fragrant odours, the nerium, jasmine, gardenia, hydrangea, Chinese primrose, daphné, heliotrope, acacia, mimosa, eucalyptus, passion-flower, amaryllis, and

calceolaria—the last very beautiful, and suitable for open air in summer.

An airy parlour or drawing-room, with windows facing the sun, may be considered a domestic greenhouse; and such apartments may be furnished with flowering plants, which will bloom and thrive if certain precautions be adopted.

The cultivation of plants in rooms, and on balconies and window-sills, is indeed so prevalent a taste that it should not be passed over in a treatise of this kind. It is, moreover, a department of gardening in which very few succeed; nor is a great amount of success attainable. The conditions upon which vegetation depends are—heat, light, and moisture. Wherever *one* of these is wanting, we have an absence or paucity of vegetation. But, as in nature we find many peculiar plants so constituted as to resist special conditions of climate, we may materially simplify our arrangements in cultivation by selecting such plants as are best adapted for those conditions to which our domestic flowers are necessarily subjected.

Our sitting-rooms are inimical to vegetation, not so much on account of the impurity of the atmosphere, or its admixture with gases poisonous to vegetation, as from the extreme dryness of the air, caused partly by the want of those terrestrial exhalations which preserve the atmosphere near the soil in a state of humidity, but chiefly arising from the drying effects of fires and stoves in rooms. We have therefore an absence of one of the elements above alluded to as essential to vegetation—namely, moisture; and no amount of moisture, however excessive, that may be applied to the *soil* will counteract the want of moisture in the atmosphere. The plants which are found to succeed best in the ordinary dry atmosphere of rooms, with least trouble, are the cacti and other fleshy plants that are enabled, by their peculiar structure, to withstand the effects of drought. In addition to these, however, many strong growing plants succeed well, with little trouble; such as the hardier sorts of fuchsias, and many of the species and varieties of pelargonium (or geranium), especially such as have scented and variegated leaves. The India-rubber tree, with its large and handsome evergreen leaves; the kangaroo vine, with its more flaccid foliage; some of the hardier palms; and many of the evergreen ferns, are admirable sitting-room plants. Many plants that require a great amount of root-moisture grow luxuriantly in rooms, such as the hydrangea and lily of the Nile. The latter is admirably adapted for a balcony or staircase, being very hardy, and having an imposing appearance, even when not in flower. Mignonette grows well in boxes of earth placed on the window-sill.

The *Hyacinth* is one of those plants of accommodating nature and hardy constitution, which can adapt themselves to a great change of circumstances, and are thus suitable for domestic gardening. It can be grown in the closest room in the most dense part of a city, without a ray of sunlight, and without a particle of soil; in fact, the neatest, cleanest, and most successful mode of managing these plants, is to place them in glasses of water, from which their roots derive all the materials requisite for healthy growth. The common hyacinth-glass is beginning to give way to 'Tye's' Registered Hyacinth-glass. This glass is made either single or triple, so as to hold one or three bulbs, the former being that shewn in the accompanying wood-cut. They are

Fig. 4.—Hyacinth-glass.

manufactured of many elegant patterns. It will be seen that provision is made for supporting the flower-stalk.

The first step in cultivation may be said to be the choice of bulbs. These should be selected as early as possible, an arrangement which will not only insure to the purchaser an extensive choice, whereby good bulbs may be secured, but they will be found to be in better condition than at a later period. In any case, they should be procured before any evidence of growth is visible, otherwise the bulb will become weakened from its tissues giving off their stores of nourishment to the central shoot of leaves.

The bulbs should be set in glasses in the month of October, the glasses being filled with water to within an eighth of an inch from the base of the bulb. If placed in the dark for a week or two after planting, the production of root-fibres will be facilitated; but a damp situation is very injurious. After the roots are somewhat advanced, the shoots develop; and during their progress, light and air should be given freely, the plants being placed as near the window as possible. They will succeed well enough, however, on a table or mantel-piece beyond the reach of the sun's direct rays; but in a room where a strong fire is kept, they should not be much exposed to its drying heat. Some growers recommend a small quantity of salt to be added to the water, but it is doubtful whether this has any beneficial effect. Mr Tye observes: A variety of methods for giving vigour to the plants, and brightening the colours of the flowers, have been resorted to—such, for example, as adding to the water a few lumps of charcoal, a little nitrate of soda, or a small portion of saltpetre; but the following has been found to answer well: Dissolve half an ounce of guano with as much chloride of lime as would equal the size of a large pea, in a quart of rain-water. Let this mixture stand for a day or two to become clear. Pour about two tea-spoonfuls into the bottle twice a week after the flower appears well out of the bulb.

The water should be changed regularly once a

week from the time of planting to the time of flowering. Soon after planting, it will be found that a quantity of decaying vegetable matter becomes partially detached from the basal portion of the bulb, inside the circle of root-fibres; this should be carefully removed by repeated washings, taking care not to injure the root-fibres, for if broken, they will not be reproduced. When side-shoots appear from the bulbs, they should be pinched off, as they draw away the nourishment from the flowers; but where two trusses of flowers appear, they should both be allowed to expand. When the flowers begin to open, the hyacinths should be placed on a table out of the sun's reach, or otherwise protected from its rays, and in as cool a situation as possible, which will prolong their period of bloom.

On the subject of the cultivation of flowers in windows, we find the following useful observations in the *Gardeners' Chronicle:* 'The three principal things requiring consideration are *air*, *light*, and *moisture.* Place them as near the glass as possible; of course windows having a south aspect possess the greatest advantage.

'Judicious watering of plants in rooms is perhaps the most important feature in their management; and it is unfortunately in most cases ill understood, being too often given mechanically, as it were at stated times, whether required by the plants or not; and by a too eager desire for their welfare, they are frequently surfeited to death with water, which is justly termed "killing by kindness," and is practised with success, especially by ladies, from a false apprehension of their wants. In summer, this cannot be easily accomplished unless the plants are allowed to stand in saucers constantly filled with water, which, by overloading them with juices, will soon engender sickly soft growths, unsuited for the production of flowers or healthy foliage. An exception to this rule is the growth of annuals in pots during summer; they, if well drained, may stand in feeders; but these, whenever used, should be half-filled with fine gravel or sand, which may be kept in any state of moisture. The best and only general rules that can be adopted are—in *winter*, keep plants, not then growing fast, rather dry; in *spring*, increase the quantity with their activity and the sun's power, keeping them in a medium state of moisture; in *summer*, water daily; and in *autumn*, decrease with the length of day, and the returning torpidity of the plants, until the dry state of winter is again reached. All this resolves in the following: Plants, when growing fast, may have free supplies of water, which must be lessened as their growth approaches maturity, and cease, or nearly so, when that is attained, until the return of their growing season. As regards *air*, similar rules to those given for watering may be followed; and indeed they are analogous. In *winter*, when the plants are not growing, large supplies of air are not so important, enough being usually given by the room-door. As *spring* advances, increase the quantity, carefully guarding against the cold of mornings and evenings, or cutting winds; and if the plants are placed out in the middle of fine days, take care to bring them in before the chill of evening comes on. After the first or second week in May, they may be set outside for the summer; and towards the end of September, or as soon as heavy cold rains occur, they should be placed again in their quarters for the winter, setting them out of doors when fine, or supplying them with plenty of air by the window, until the cold weather and decrease of moisture at the roots bring them to a state of comparative rest. It should be remembered in spring and autumn that the plants must not go out to-day because they were placed out yesterday, but the weather alone must determine; sudden changes must at all times be avoided. The leaves of plants act as lungs, by which they breathe; if they become dirty, their respiration is impeded; therefore, an occasional careful sponging will be useful to them. In spring and summer, allow them the full benefit of genial showers, which will do them more good than any artificial watering. Never use spring-water if soft or rain water can be had; and always let it be about the same temperature as the air in which the plants are growing. It is hardly necessary to mention the removal of decaying leaves and flowers; the last are exhausting as well as unsightly.

'One principal potting is usually required, and afterwards as often as the plants may fill their pots with roots, or seem to require it. The most important thing is good soil, which, if composed of three parts loam, of a fibrous open texture, with a fourth of dung, most plants will thrive in, using plenty of drainage to allow water to pass off readily. Never suffer the surface-soil in the pots to become hard or moss-grown, but let it be loosened occasionally with a piece of stick.

'Succulents are well suited for growing in rooms, as they are not so impatient of either air or water as most other plants; and the abundance of their beautiful flowers renders them objects of interest. Cactus speciosus, Jenkinsonii, flagelliformis and speciosissimus; mesembryanthemums, and flowering aloes, deserve especial notice.'

All that is necessary for successful indoor culture is attention to the general directions given above. If plants have sufficient air, light, warmth, and moisture, and be potted in proper soil, nothing else is needed, save a little care in keeping them clean, occasionally stirring the upper portion of the soil, turning them regularly to the light, lopping off old wood, pruning unseemly shoots, and removing decayed leaves. It may sometimes happen, notwithstanding all ordinary care, that a few, such as the pelargoniums, may be infested with small green insects, or may otherwise take disease and languish. The former are generally destroyed by a sprinkling of powdered lime, a dusting with pepper, or some of the insect-killing powders sold in the seed-shops, the fumes from a tobacco-pipe, or even, where the nature of the plant will admit, by a thorough drenching with pure water.

Another direction to be borne in mind is, never transfer a plant from one situation to another of a widely different character without some previous preparation. Vegetables no doubt possess wonderful powers of accommodation, but there is a limit to this principle; and a plant reared in the hothouse will no more endure the sudden exposure of open air than the animals of India could live and propagate in Iceland. Thus many of our rarest exotics are permanently injured by *sudden* removal from the stove to the open stand, or from the open air and conservatory to the drawing-room. Plants intended for transferences of this kind should either be taken at the period of their repose, or

immediately before their breaking into blossom, if their flowers be the object in view.

POTS AND STANDS.

Since the main object of domestic floriculture is to improve the taste for what is lovely and ornamental, it should be the aim of all growers who can afford the outlay to procure pots of as handsome shapes as possible. The common earthenware pot is often very clumsily made, though not of itself an inelegant object; but others may be constructed with ornamental mouldings in relief, or in the form of vases, urns, and the like, which add greatly to the grace of a flower-stand. Pots may also be constructed of stone, of polished slate, of cast-iron, wood, and the like, and in highly elegant fashions, either to be set on plain shelving or on ornamental stands. Elegance, however, does not consist in exuberance of ornament, and correct taste will avoid all grotesque and fantastic shapes. There is an endless variety of pots; some intended to afford better drainage than the common sort; others whose main object is display and ornament. Whatever be their form, gardeners distinguish them by numbers, thus: The smallest ones are called *thumb-pots;* the next, *sixties,* which are 3½ inches deep, and 3½ inches wide at top; *forty-eights* are 4½ inches deep, and 4½ inches wide at top; *thirty-twos* are 5½ inches deep, and 5½ inches wide at top; *twenty-fours,* 6½ inches deep, and 6½ inches wide at top; *sixteens* are 8 inches deep, and 7½ inches wide at top; *twelves* are 8½ inches deep, and 8½ inches wide at top; *eights* are 9 inches deep, and 9 inches wide at top; *sixes* are 10 inches deep, and 10 inches wide at top; *fours,* 11 inches deep, and 11 inches wide at top; *twos,* 12 inches deep, and 12 inches wide at top—all inside measure. The actual sizes vary, however, with different manufacturers.

Fig. 5.

Stands are commonly made of wood or cast-iron; but we have also seen very cheap and pretty ones constructed of a wooden upright, with suspension arms of stout iron wire. Wooden ones, with plain shelving, of circular, or semicircular, or quadrantal forms, make very handsome stands for recesses and corners; those on single uprights, with branches for the support of the pots, are usually constructed of iron wire, or of cast-iron painted, and are best adapted for central situations in lobbies and drawing-rooms. It may not, however, be in the power of some to procure flower-stands of either description; and for such, one board placed in the window-recess, so as to bring merely the top of the first row of pots within influence of the light, and a second level with the top of the first pane, will make no inelegant display; the effect of which will be heightened by suspending some light pots from the lintel above, containing such hanging-plants as that called Humility (*Linaria Cymbalaria*). Pendent plants, in fact, form very handsome appendages to a dwelling-apartment, and no amateur should be without some to grace his collection. Of these may be mentioned, as worthy of adoption, Saxifraga sarmentosa, Disandra prostrata, Indian strawberry, epiphyllous Cacti, ferns, lycopodiums, &c.; and, with a little management, the prostrate verbenas, lobelias, and mimuluses, the trailing mesembryanthemums, with Campanula rupestris, fragilis, hirsuta, and a multitude of plants which resemble them in their habits. Even some annuals, flowered in early spring, as Nemophila maculata and insignis, create a good display when suspended in pots; and many of the tender creepers hereafter mentioned may be trained pendent as well as erect. It must be kept in view, however, that the atmosphere of a room is *usually* too dry for such plants.

WARD'S CASES.

It may happen, from the vitiation of the air in towns and in dwelling-apartments, or from other circumstances, that it is impossible to grow the plants we most wish in open pots. To remedy this, a plan was many years ago devised by Mr Ward, a surgeon in London, of keeping the plants under close glazed frames, in which situation they grow and flourish in perfection. These frames are generally known by the name of Ward's Cases, and may be seen constructed of every shape and size, according to the taste or means of the grower. By aid of these, any one, whether inhabiting the most humble or the most splendid dwelling, provided it be freely exposed to the sun's light, has it in his power to cultivate a miscellaneous collection of plants, at an expense so trifling as to be within the reach of the most moderate circumstances. One of these cases, of a very complete structure, is represented, with its collection of plants, in the following figure. On the

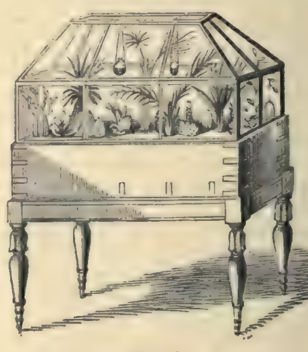


Fig. 6.

stand or table is a strong box, lined with zinc or lead, and filled with well-moistened loamy soil, underlaid by a thin subsoil of turfy loam, and this resting on a porous stratum of gravel, or broken earthenware. This composition is meant to represent a natural fertile soil, which it does to

perfection, the water lodging among the gravel till the wants of the plant in the superior mould require it. Over this box is placed a close-fitting glass cover, which completes the apparatus. The lighter and thinner the glass-frame, and the finer the glass, the better are the plants exposed to view, and the more readily do they receive the sun's light. This plot of soil, with its glazed framework above, forms a little world of itself, in which the plants grow and flourish. When the moisture of the soil within is vaporised by the heat of the sun, it collects on the inside of the glass, and trickles down again, so that the plants are never subjected to irregular or capricious watering. The case is not absolutely air-tight; if it preserves a certain regular amount of moisture and warmth, while it excludes dust, soot, smoke, and other noxious fumes, it does all that is required. The Ward's Case may be large enough only to cover a single plant, or to become a domestic conservatory.

Cases of the kind described may be used either for indoor or open culture, and answer as well for a little front-plot or back-court as for a drawing-room. They can be also conveniently put up in balconies, or even over the entire window, so that the panes may serve for one side of the conservatory. Many such are now to be seen in our large towns, even in the smokiest and least inviting quarters. This sort of double window, if we may so speak, is admirably adapted for tall plants and flowering shrubs, or for suspending pots, and is altogether a very pretty annexation to a dwelling. Lofty and partially close cases of this sort are fitted for almost every species of greenhouse plant; natives of damp and shady situations grow and bloom in them to perfection; but the moistened and shaded atmosphere of a small and closely fitted case is destructive to many flowering plants. Among those most suited for Ward's Cases are many lovely and rare plants, which will amply repay the attention of the case-grower; such as ferns, lycopodiums, and mosses.

Rare exotics need not, however, be sought after. 'The plants to furnish it,' says Mr Ward—who, however, uses cases of *large* size—'can be procured abundantly in the woods in the neighbourhood of London. Of these I will mention a few. The common ivy grows most beautifully, and can be trained over any part of the case, agreeably to the pleasure of the owner. The primroses, in early spring, will abundantly repay the labour of fetching them, continuing for seven or eight weeks in succession to flower as sweetly as in their native woods. So likewise does the wood-sorrel, the anemone, the honeysuckle, and a host of other plants, independently of numerous species of mosses and of ferns. Some of these latter are more valuable than others, in consequence of the longer duration of their fronds, such as *Lastræa dilatata*, and its numerous varieties. There are likewise many cultivated plants procurable at little or no cost, which grow without the slightest trouble; such as the *Lycopodium denticulatum*, the common musk-plant, myrtles, jasmines, &c. All the vacant spaces in the case may be employed in raising small salads, radishes, &c.; and I think that a man would be a bad manager who could not, in the course of a twelvemonth, pay for his case out of its proceeds. These remarks apply chiefly to situations where there is but little solar light. Where there is more sun, a greater number and variety of flowering plants will be found to thrive; such as several kinds of roses, passion-flowers, geraniums &c. with numerous beautiful annuals—namely, *Ipomæa coccinea*, the species of *Nemophila*, *Convolvulus*, and a host of others: the vegetation, in fact, can be diversified in an endless degree, not only in proportion to the different degrees of light and heat, but likewise by varying the quantity of moisture; thus, with precisely the same aspect, ferns and bog-plants might be grown in one case, and aloes, cactuses, mesembryanthemums, and other succulent plants in another.'

Case-grown plants, after the first preparation, require little or no care; the case need only be opened for the removal of dead leaves, or for a little trimming when required. Plants in open flower-pots are exposed to the vicissitudes of change of climate, and require constant watering; but the plants in these cases seem to be independent of any change of temperature in the air, and water themselves. The moisture rises by the sun's influence from the moistened earth, refreshes the leaves of the plants in its aërial condition, and during the cool of night, falls to the earth again like rain or dew. In this manner there is a constant succession of rising and falling of moisture, in imitation of the great processes of nature daily going on in the fields around us.

WALLS AND TRELLISES.

Where it is objectionable to fasten climbing-plants to walls, a light trellis-work of wood or iron wire may be employed; permanently fixed where the climbers are perennial, but movable where they are grown merely for summer purposes. By being removed in autumn, and kept dry, a wooden trellis, originally of small cost, will last for a number of years; while its removal, along with the withered branches of the plant, is a positive improvement to the appearance of the dwelling. Nettings of string or wire make very convenient leaders when other material cannot be had; and these may be woven along the outside of doors and windows, where other frameworks might not be permitted.

Among the *hardy* species adapted for trellis-work and walls are the honeysuckle, the ivy, many varieties of the rose, the jasmine, the small and other kinds of clematis, the Pyrus Japonica, Lathyrus, or even the hop, where an easily nurtured and quick-growing climber is wanted. For summer purposes merely, a selection from the following genera may be made: Cobæa, several species; Convolvulus; Lathyrus, several; Lophospermum, several; Maurandya Barclayana; Tropæolum, several; Passiflora cærulea.

It has been often remarked that, of all flowering plants, climbers present the most graceful forms which can be contemplated under the open sky; but true as this may be, the tender varieties are not the less graceful when cultivated in the greenhouse. Grown in pots, and sustained by appropriate frameworks, they can be trained to almost any shape, be it urn, vase, obelisk, or pillar—a screen of living network, or a fairy arbour. Trellises affixed to the outside of pots can be had of a thousand designs, and they may be constructed of wicker, slender painted rods, cord, or copper wire, which is one of the most pliable and durable of

materials. By the adoption of this plan, with frequent prunings, climbers may be made to clothe a trellis not more than a few feet high, and so requiring no larger space than a small shrub, flowering profusely. Climbers are usually not of difficult culture, for we have seen a cottager's window shaded within by a screen-work of leaves and blossoms, more effectually than it could have been by the costliest Venetians.

ROCK-WORK AND AQUARIUMS.

If space and means permit, a flower-garden may be much improved by introducing a piece of artificial rock-work and a small pond; because, in connection with these, certain highly interesting plants may be reared, which would not answer on a plain surface. In order to increase the effect, the pond should be at the base of the rock-work, and receive from it the trickling of water which has been conveyed to the summit in pipes. Let the rock-work have a natural appearance, with rugged sides, and perhaps be ten or twelve feet high. Rocks of the same kind and colour should be placed together. A dark cave, penetrating into the thickest part of the erection, is not very difficult to construct; and when encircled with ivy, it will form an interesting object. Rock-plants of every description should be profusely stuck around, and in twelve months the whole scene will exhibit an impress of antiquity far beyond anticipation. The undertaking, when completed, will present a field of varied and interesting study, and more than compensate for all the attention and outlay bestowed upon it. The aquatic and rock plants, which formerly were 'far to seek and ill to find,' will thus be brought within the range of everyday observation. If the situation is secluded and in the country, the wagtail, oxeye, and stonechatter may be attracted to the spot, not perhaps because they are lovers of the picturesque, but because they find everything here suited to their nature; and colonies of the wild-bee will soon be seen and heard around the interstices of the rocks. A weeping-willow adjoining one or two mountain-ashes, and some of the hardy varieties of fuchsias mirrored in the lake, will add materially to the beauty of the scene; and if the spot be airy, there might, with advantage, be planted, on the top of an eminence, the *Scottish thistle.*

Among the plants suitable for growing from the crevices of the rocks may be mentioned various heaths and mosses, many kinds of sedums, house-leeks, and saxifrages, rock-roses, ferns, and numerous 'alpine' plants. Of plants suitable for the marshy borders of the pond, may be named the mountain pride, grassy Parnassus, American pitcher-plant, flowery rush, butterwort, Acorus, Littorella, Lychnis floscuculi, Primula farinosa. While in the water, places should be given to various kinds of water-lilies—those lovely Naiads that adorn the lakes and rivers with their ample foliage, and, raising their gorgeous flowers with the morning sun, recline them 'in graceful attitudes to rest,' as the god of day sinks in the western horizon. The use of these plants in outdoor landscape-gardening—especially in lake-scenery, for which their expansive foliage and showy flowers render them so well adapted—has arisen chiefly from the attention recently attracted by the gigantic *Victoria regia*, the Royal Water-lily of South America. This magnificent plant, with its gigantic leaves, eighteen feet or more in circumference, and delicate rose-coloured flowers thirty-six inches round, is represented in the frontispiece. Being an aquatic of such huge proportions, it requires for its successful cultivation a special structure, with a large central tank of water; but this may be made available for the culture of other aquatics, and the Victoria regia has thus led to the extended culture of exotic aquatic plants. Many new kinds of these have been recently introduced, especially species of *Nymphæa*, among which there is indeed great variety of colour and form, from the little *Nymphæa pumila* to the huge *N. gigantea.*

Some beautiful designs have been published shewing the applicability of aquatic gardening to the imitation under glass of tropical scenery; but we prefer representing here a simple diagram

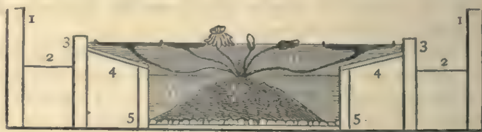


Fig. 7.

1, Outer wall of the building; 2, Foot-path; 3, Outer wall of the tank; 4, Bank of soil; 5, Inner wall of the tank; 6, Water; 7, Mound of soil in which the plants are rooted.

(vertical section) of a tank for exotic or hardy aquatics, believing that any one can readily adapt it to the size and circumstances of his garden, and render it picturesque according to the means at disposal.

THE PARLOUR AQUARIUM.

The parlour aquarium or vivarium forms an interesting companion to the Ward's Case. It may, in fact, be described as a combination of that and the gold-fish globe; one object being, in addition to the cultivation of plants, the illustration of the mutual dependence of animal and vegetable life. The parlour aquarium consists usually of a water-tight box with glass sides, which may be of various forms, and of size corresponding

a *b*

Fig. 8.—Vallisneria spiralis:
a, female plant; *b*, male plant.

with the object of the cultivator. The bottom of the box is lined with soil and picturesque fragments of rock, amid which are planted various aquatics, such as Vallisneria spiralis (fig. 8), Anacharis Alsinastrum, species of Callitriche, bladderworts, and other neat aquatic plants.

Aponogeton distachyon, although usually a large and unwieldy plant, is admirably adapted for such cases. In addition to the plants, gold-fishes, sticklebacks, and other small fishes may be introduced—even the lamprey, perch, and pike, if the aquarium be large enough; together with fresh-water mollusca — such as species of Cyclas, Planorbis, Limneus, and Physa. The mollusca multiply to a great extent, affording food for the fishes. The plants consume the carbonic acid produced by the animals, appropriating the carbon, and setting free the oxygen in a gaseous state, again to support animal life. It is a great mistake to suppose that a large vessel

Fig. 9.

is required. We have already mentioned incidentally that aquatic plants may be grown well in an ordinary fish-globe; and the above wood-cut represents a simple form of aquarium, measuring about eight inches across, which affords ample accommodation for water-plants, such as Callitriche, Vallisneria, Anacharis, minute Algæ, &c. with mollusca, hydras, cyclops, and other small animal forms; and a series of vases of this kind will be found more useful by the *microscopical* observer than an aquarium of larger size. Where, however, it is the object to study the habits of fishes and the larger plants, an aquarium of several feet in length, and corresponding depth of water, must be obtained.

Even more interesting than the ordinary aquarium is the marine vivarium, in which are introduced, in *sea*-water, the beautiful red and green sea-weeds, corallines, fishes, marine mollusks, nudibranchs—those graceful *ferns* of the animal kingdom—star-fishes, sea-mice, sea-anemones of varied form and hue, and all the other exquisite forms of life that swarm in old Ocean's caves. In forming the vivarium, sea-weeds must be procured, attached to a portion of their native rock. Where animals have to be taken to a great distance, they are frequently more safely conveyed in moist sea-weed than in sea-water itself. In March 1856, we spent a pleasant afternoon on the shores of the Isle of Wight, and got some prizes in the way of nudibranchiate Mollusca; these were hastily placed in a botanical vasculum among some sea-weed. We crossed to Portsmouth, took the night-mail to London, arrived at Waterloo Bridge at four in the morning, took a peep at the smouldering ruins of Covent Garden Theatre, left our card at Bedford Square for a friend with whom we had promised to dine on our way north, took train at Euston Square at six, and finally reached Edinburgh at ten o'clock the same night. We opened our box, and the nudibranchs were all alive!—those fragile things, that the merest touch of a finger seemed sufficient to destroy. They were placed in our vivarium, and thus had we the pleasure of examining their beautiful forms, and studying their habits, as well as if the Isle of Wight, with its fertile shores, had been brought into the Firth of Forth.

GARDEN-PLOTS IN TOWNS.

The attempt to have a neat and flourishing garden or garden-plot in populous towns is very often defeated by the abundance of smoke and other impurities in the atmosphere; for, as repeatedly mentioned, pure air is essential to the proper growth of plants. It is found, however, from experience, that certain kinds of shrubs and flowering herbs are less delicate in this respect than others; and that, with a reasonable degree of care, open plots in towns may be made to yield a surface of vegetable bloom and beauty. On this branch of flower-culture, so important to many town-residents, there appeared some years since a well-written paper in *The Magazine of Domestic Economy*, describing the experience of an amateur florist. We take the liberty of extracting from it the following passages: 'When I first took possession of my garden [in town], I found it encumbered with old lilacs and laburnums, the common aster, and other ordinary plants. These I immediately removed: by my west wall I planted a Buddlea globosa and a Virginian creeper; and by my south wall, which was partly covered by a vine, I planted the Jasminum revolutum, the small white clematis, and the Pyrus Japonica. The last grew luxuriantly, and bore an abundance of flowers, which, glowing upon the light wall, enlivened my prospect in winter. I had much of the south sun in my garden, but none of his morning beams reached it, and there was a corner which never had a gleam at all. In this spot I planted a quantity of roots of the lily of the valley, and they flowered well, although late. The laurustine also grew well with me; and I should strongly recommend this pretty shrub, together with the laurel, instead of those deciduous shrubs which we see in town-gardens. Besides this, the untidy appearance of their falling leaves is a great annoyance. My jasmine grew quickly, and, with the clematis, soon covered as much wall as I could afford to them. The common Provence roses, both white and red, flower well in the town; but it is vain to attempt the China—it requires a very pure air. I have tried many other roses, and found the Tuscan, the rose de Meaux, the Tudor, the little early crimson, and the Bengal celestial, flower extremely well.

'With regard to spring-flowers, the snowdrop I could not tolerate in the city—the smoke robbed it of all its beauty; the crocus, either the mice or the sparrows would not leave undisturbed; and after replenishing the edge of my border several times, I gave up the matter. The hepatica and gentianella flowered well with me; anemones also I had of very good colours. Heart's-eases pined away after the first year, but they were

easily replaced, and they were too ornamental to be relinquished. Then followed the white lily, and a variety of irises, all of which increased fast, and flowered abundantly. The peony I could never persuade to flower. My buddlea was every spring covered with its golden balls, and grew so quickly that I scarcely knew what to do with it. I am surprised this beautiful shrub is not more common. The magnolia grows quickly and flowers abundantly in the city upon a south wall; and the arbutus is not at all particular with respect to situation. The Bignonia grandiflora also does not withhold its scarlet trumpet-like blossoms in the immediate vicinity of a steam-engine. To return to my garden, the glory of which in the autumn was the Lobelia fulgens; I managed it thus: I sank in the ground up to the rim, a large and deep seed-pan; this I filled to about three-quarters of its depth with rich soil, properly mixed, and planted my roots. As soon as the shoots appeared, I supplied them plentifully with water, and from time to time added more soil. The sweet-scented marvel of Peru thrived well with me, and the tiger-flower also. Carnations and picotees I tried one year, but was so much disappointed in the result that I gave them up, although very reluctantly, as I believe carnations do not require a very pure air; and I have fancied since that my failure with them arose from some other cause than the smoky atmosphere. Dahlias also I gave up. The Amaryllis lutea flowered well with me when once established, and the Hemerocallis cærulea and flava did the same.'

In addition to the forenamed, the 'London pride,' and several other free-growing, evergreen saxifrages, are highly suitable herbaceous plants for the flower-borders of town-gardens, as are also some of the stone-crops, house-leeks, green and golden 'Creeping Jenny,' common and major periwinkles, &c.; while among evergreen shrubs, the now numerous varieties of aucuba all succeed well, as do most of the free-growing varieties of the holly, and a number of the more robust-growing rhododendrons. For covering town walls, most of the many variegated and green ivies will be found useful, as are also different species of cotoniasters, and several of the recently introduced large-flowered clematises, Japanese ampelopsis, the winter-blooming Chinese jasmine, and some of the most vigorous hybrid roses.

FLORICULTURAL MONTHLY CALENDAR.

January.—In open and dry weather, make the walks, plots, and borders neat. Propagate, by division of roots, daisies and thrift; protect the beds of hyacinths, anemones, ranunculuses, and tulips, by a covering of coarse litter. Top-dress auriculas, using a compost of light loam and two-year-old cow-dung, mixed with a twelfth each of sea or river sand. Sow mignonette, stocks, and other half-hardy annuals, in heat.

February.—Attend to the foregoing general directions; cut turf for lawns; fork and clean the flower-borders. Plant anemones and perennial herbaceous roots; and transfer others, dividing the crowns, to multiply the species, such as the primrose, single and double, and the polyanthus. Transplant carnations, also the divided roots of campanula, lobelia, lychnis, mulepink, and Dianthus sinensis. Sow, in mild heat, any annual flower-seeds, and auriculas and mimuli, in boxes or pans. Excite choice dahlia-roots, placing them in hotbed frames, or in troughs or pots of old tan, or any light moist substance, on the floor of a stove or vinery at work.

March.—Sow, under glass, tender annuals, including balsam-seed, collected from the best double flowers. Plant box-edgings; also shrubs of every description. Transplant autumn-sown annuals, and protect them till fresh-rooted; as clarkia of every kind, mignonette, schizanthus, &c.; and sow, under glass, stocks, China aster, clarkia, dahlia, campanula, larkspur, pentstemon, amaranthus, tobacco, and all the hardy annuals. Take cuttings of hydrangea from the tops of the shoots; these, if the buds be full, sometimes will produce a fine flower-head, and the effect is striking.

April.—Plant evergreens, gladioluses, hollyhocks, carnations, and other biennials and perennials, for flowering; at this season every herbaceous plant is almost certain to succeed. Propagate, by cuttings, salvias, verbenas, rockets, and fuchsias. Divide the roots of dahlias, either retaining one single tuber with a sprouting eye, or twist out very cautiously a single shoot, so as to detach it from the base, planting it in the smallest pot of sand and leaf-mould; a gentle hotbed will facilitate the protrusion of roots. Sow most of the hardy annuals in the open ground; as also pansies and most others in pots.

May.—This is the season to stock the flower-garden with those plants which have been prepared during autumn, winter, and spring; and therefore transfer, from the propagation-pots, annuals raised in them, by lifting the whole mass, and depositing it in a spot prepared in the border: thus trouble and loss of time are obviated. Sow annual seeds in the open ground for succession. Plant the parterres with groups of fuchsia, calceolaria, petunia, verbena; and at the latter end, form masses of the scarlet and variegated geraniums, as well as of the stage and fancy varieties. Propagate, by cuttings, China-roses of every kind, planting them two joints deep, in a shady situation; also calceolarias of the shrubby kind, Peruvian heliotrope, &c. Propagate, by slips, lychnis, double rocket, pansies, and wallflower; thin out the superabundant shoots of perennial asters, antirrhinums, pentstemons, phlox, and all luxuriant herbaceous plants.

June.—Propagate, as during the last month. Plant young side-shoots of hardy lobelias, in shady borders, under a hand-glass. The pipings of pinks, placed in sandy earth, are to be closely covered in the same way, till completely rooted. Greenhouse plants may now be arranged in a north aspect; the pots to stand on a deep stratum of coal-ashes. Azaleas, Acacia armata, heaths, rhododendrons, and such plants, are greatly improved by being turned out of pots, and planted with the entire balls in an open peat-border.

July.—Bud roses on wild stocks. A pretty effect is produced by inserting one or two buds of the deep-red China in the common China-rose; the different tints of the two roses are very pleasing. Propagate, by cuttings, the Chinese azaleas, half-shrubby calceolarias, linums, pelargoniums, fuchsias, myrtles, and other exotic shrubs. Layer carnations in sandy earth; peg them near the incision with hooks of fern-fronds. Sow mignonette in small pots for winter; also annual flower-seeds for bloom in September.

August.—Bud roses as before. Plant seedling herbaceous plants; repot auriculas, removing the suckers, and detach the black ends of old roots with the finger and thumb. Sow the seeds of annuals and pansies. Take cuttings of all the fine pelargoniums that are out of flower early in the month; also of calceolarias, shrubby and half-shrubby; and of antirrhinums, pentstemons, which require no heat, but should be placed in a cold frame.

September.—Plant the crocus and other early bulbs. Transplant herbaceous perennials and pinks to permanent beds, if perfectly rooted. Propagate, by cuttings, China-roses in the open borders; also petunias, heliotrope, salvias, geraniums, calceolarias, &c.; they require only a hand-glass and light soil, or slight bottom-heat. Sow auricula seeds in pans in the greenhouse; also clarkia, collinsia, and other annuals, to be preserved in pots all winter. If the pyramidal campanula be out of flower, take up one of the finest roots; break it to pieces, and half-filling a large pot with loam, place the pieces on the earth, fill the pot with loam, and keep it merely protected from frost all winter. Raise every geranium or other greenhouse plant now in open ground, and repot in soil suitable to each. Cut back to low buds the scarlet and other geraniums, and place all the plants under glass, to recover from the removal; make cuttings of the best amputated shoots of geranium. Gradually diminish the watering of all greenhouse plants.

October.—Plant, towards the end of the month, bulbs of the hyacinth, narcissus, and tulip, the common jonquil, and daffodil, and common anemone roots, &c.; also shrubs of every description. Hyacinths, in pots, filled with a compost of light loam, sand, and vegetable earth, should be plunged to the rims in ashes, or light earth, under the glass of a cold frame; and when the plants begin to grow, the pots should be raised, cleaned, and placed in the greenhouse. Greenhouse plants must now be taken in, and gradually inured to winter treatment, by the free admission of air and abatement of water.

November.—Plant all bulbs, employing much sand about and above the bulbs. Protect fuchsias, if frost threaten. Screened leaves form the best substance to be placed as mulch. Dahlias should be taken up in airy and dry weather, when quite dry and clean: preserve the tubers in well-dried sand.

December.—Protect beds of tulips, hyacinths, and other choice bulbs or roots, with a layer of sawdust mixed with sand, or with ashes. Sawdust alone has been found the most effectual protector to the roots of potted plants in frames, the pots being plunged in it to the brims. If dry weather permit, lightly fork the surface of plots and borders; if it be frosty, scatter some light manures around the stems of roses and the more tender shrubs.

Fruit.

THE FRUIT-GARDEN.

GENERAL MANAGEMENT.

FRUIT-TREES are either grown as independent plants in an orchard, in which case the tree is suffered very much to assume any height or bulk that nature permits; or they are trained upon walls and espaliers, or constrained to grow in pyramidal or other forms. In whatever manner the tree is planted, or designed to grow, the tendency of the main stem and branches of the plant is upwards into the atmosphere, and of the chief roots, downwards into the soil. In general, the depth and spreading of the roots are proportional to the height and spreading of the branches, because the roots are the anchorage and food-seekers of the plant, and require a depth and compass of soil corresponding to the bulk of the tree and its demands for nourishment. It is therefore of the first importance not to stint fruit-trees of a depth and breadth of good sound mould adapted to their expected dimensions. Trees close to walls should have a depth of soil from two to two and a half feet.

In planting fruit-trees, never put them deeper into the soil than they have previously been, and in dampish or retentive soils, it is better to keep them three or four inches higher, mounding up the soil around them to that height; pits should be made for them at least a foot beyond their roots, when these are regularly spread out. To facilitate the root pruning of wall and espalier as well as dwarf standard trees, it is a good plan to lay a paving-stone two or three feet wide, at about 18 inches deep, immediately under their stem; and after filling in the pits with a mixture of loam, thoroughly rotted dung and leaf mould, the surface should be covered as far as the roots extend with two or three inches of dung, to exclude drought.

Grafting—Budding—Inarching.

Fruit-tree stocks are propagated by means of seeds, cuttings, or layers, and desirable kinds are afterwards inserted upon them by grafting, budding, or inarching.

Grafting, which is a practice of great antiquity, may be stated in principle to be the union of two individual plants in a growing state, through the medium of the circulating juices.

Gardeners assign various reasons for grafting: 1. The perpetuation of varieties of fruit, which could not be insured by sowing seed; 2. Increasing, with considerable rapidity, the number of trees of any desired sort; 3. Accelerating the fructification of trees which are tardy in producing their fruit; and 4. Changing the sorts of fruit of an old tree, and renewing its productiveness; for when a tree becomes old, but has still healthy and vigorous roots, and it is thought advisable to renew or improve its fruitful qualities, it is cut off across the lower part of the stem, and forms the *stock* on which *scions* are ingrafted, which scions become in time the fruit-bearing branches of the tree. The wild apple-tree, which bears only crabs too sour to be eaten, forms one of the best stocks on

which to graft good apples. The notice of this fact leads to a consideration of what are the radical principles on which improvement is effected by grafting. On this intricate subject we subjoin the explanations of Dr Lindley: 'In proportion as the scion and stock approach each other closely in constitution, the less effect is produced by the latter; and, on the contrary, in proportion to the constitutional difference between the stock and the scion, is the effect of the former important. Thus when pears are grafted or budded on the wild species, apples upon crabs, plums upon plums, and peaches upon peaches or almonds, the scion is, in regard to fertility, exactly in the same state as if it had not been grafted at all; while, on the other hand, a great increase of fertility is the result of grafting pears upon quinces, peaches upon plums, apples upon white-thorn, and the like. In these latter cases, the food absorbed from the earth by the root of the stock is communicated slowly and unwillingly to the scion; under no circumstance is the communication between the one and the other as free and perfect as if their natures had been more nearly the same; the sap is impeded in its ascent, and the proper juices are impeded in their descent, whence arises that accumulation of secretion which is sure to be attended with increased fertility. No other influence than this can be exercised by the stock upon the scion. Those who fancy that the contrary takes place—that the quince, for instance, communicates some portion of its austerity to the pear—can scarcely have considered the question physiologically, or they would have seen that the whole of the food communicated from the alburnum of the quince to that of the pear is in nearly the same state as it was when it entered the roots of the former. Whatever elaboration it undergoes must necessarily take place in the foliage of the pear—where, far from the influence of the quince, secretions natural to the variety go on with no more interruption than if the quince formed no part of the system of the individual.' It must be kept in view, however, that we have no very satisfactory course of experiments on record to shew the precise reciprocal influences of the graft and stock. For an instructive discussion of the subject, see Dr Lindley's paper in *The Gardeners' Chronicle* of the 6th of June 1857.

The season for grafting is about the middle of March, when the sap is rising and the buds beginning to swell. The grafting should not take place immediately on cutting the scion: after removal from its parent stem, place it in the ground for a few days, so that it may be partially exhausted of its juices, and be more ready to receive the ascending sap from the stock. Keep it in dry ground, and not exposed to the sun. A scion may be brought safely from a distance by being stuck in a raw potato. Before applying to the stock, cut the extremity of the scion afresh.

Tongue-grafting, by which a tongue or slice raised in the sloping cut of the scion is inserted in a corresponding notch of the stock, is the more common method. The young stem of the stock is cut across, so that the scion which is added forms the stem of the future tree. The cut in both pieces requires to be smooth, and the joining so neat, that the inner or liber bark on one side of the scion must be even with that of the stock. Having joined the two pieces, bandage them with a flat strip of mat, but not so tightly as to prevent circulation or the expansion of the scion. Over the bandage, plaster all round with a handful of clay and horse-dung well mixed together, taking care not to disturb the united edges. This mass will form a hardened lump, and may remain till the young growth has pushed four to six inches; and when the union has become complete, it should be taken off, and the graft tied to a stake, so as to prevent its being broken by wind.

For an account of the process of *budding*, which is analogous to grafting, we refer to the number on THE FLOWER-GARDEN, page 564.

Inarching, or grafting by approach, is an ingenious mode of grafting, by which one growing plant, without removal, is made to strike upon another plant, and thus form a union. It may be performed in various ways, as represented below.

For example, two branches of a tree (*a*) may be bent so as to meet and strike upon a wound in the main stem, by which a gap will be filled up; one growing tree (*b*) either from the ground or a pot, may be led to unite with another; or several suckers (*c*) may be led from the ground archwise to strike upon a point in the stem, thus bringing fresh aid to the productive part of the tree. By means such as these, hedges are sometimes formed like a network, so as to combine lightness in appearance with their protective qualities.

CULTURE OF FRUIT-TREES.

The Apple.

The apple-tree is believed to have been introduced into Britain by the Romans. It was much cultivated in the gardens of monasteries during the middle ages, and from that source the greater number of our varieties have their origin. The apple-tree, if favoured by a good soil and climate, will live to a great age, two hundred years being not an unusual duration in a fruit-bearing condition. Some orchard apple-trees now existing in Herefordshire are said to be a thousand years old, while others were brought over by the Normans in the time of William the Conqueror.

The varieties of cultivated apples are now innumerable, several thousands being described in catalogues, but all may be classed into three groups—namely, apples for the *table*, or to be eaten raw; apples suitable for *baking* and other culinary purposes; and apples for *cider*. Table-apples are again subdivided into those which will keep, and

those which will not. The choice kinds at present include the Ribstone pippin, which will keep till March, but is in its prime about Christmas; the Dowton nonpareil, scarlet pearmain, and Blenheim orange. The Keswick, Manx, and Kentish codlings, Lord Suffield, Ecklinville seedling, and Hawthornden, are early ripe, but the fruit will not keep beyond October or November. The nonsuch is a fine apple, and remains good in November. The old nonpareil is in every respect deserving of its title; its flavour is high and musky, and it keeps long. Other choice long-keepers are the scarlet nonpareil, the golden harvey or brandy apple, the winter pearmain, and the Easter apple, commonly called French crab. The best baking-apples are the Colvilles for early use; the rennets and pearmains for autumn; the russets and Padley's pippin for winter and spring. To this short list, hundreds might be added; but those who can grow what we have enumerated, and bring them to their full complement of bearing, can require no others as stock-trees. It must always be borne in mind, however, that what will succeed well in one garden may not do so in another, and that experience as to soil and climate, independently of advice from skilled neighbours, will in every case be necessary in the proper and profitable conducting of the fruit-garden.

For *cottage-gardens*, where the soil and situation are favourable for the production of the apple, the following sorts are recommended by Mr Thompson: Where the space will admit of only one tree, the best is the Ribstone pippin; where two, add the Dutch mignonne; where three, the Wormsley pippin; where four, king of the pippins; where five, the old nonpareil, or the Dowton nonpareil; where six, the Alfreston; where seven, the Wormsley pippin, king of the pippins, Ribstone pippin, Alfreston, Dutch mignonne, old nonpareil, and Dowton nonpareil. Beyond this, Pennington's seedling and any other good sorts may be added. Mr Loudon observes, in the *Encyclopædia of Gardening:* 'It often happens that one or more trees can be trained against a cottage wall or roof, or against some wall appertaining to a cottage; in these cases, the proper sorts are Ribstone pippins, old nonpareils, and if a large kitchen-apple be required, the Bedfordshire foundling. In situations liable to spring frosts, which so often kill the blossoms of the generality of apples, the Court pendu plat is recommendable, as its blossoms expand very late in the season. Under less favourable circumstances, where the Ribstone may not succeed, the Bedfordshire foundling will be a hardier substitute, or the king of the pippins, which is still hardier; the northern greening may be planted for late kitchen use. For an autumn-apple, perhaps none in this case is more to be recommended than the Lord Suffield. To these observations, we need only add, that the cottager will do well in all cases to prefer one or two copious-bearing trees to a number of fancy and fickle varieties; but he may increase his kinds by grafting several on one tree.

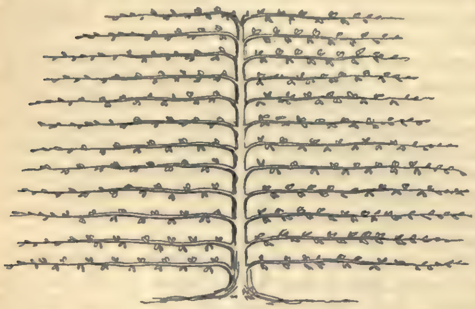
Standards.—Pruning and Training.—Standards are those trees which grow independently in open ground, and are classed as Large and Dwarf Standards. The proper object of cultivation is to give figure to the tree, of whichever kind, and bring it to a fertile or mature condition. Apple and pear trees, as they approach to maturity, develop short *spurs* along the entire extent of the branches, and those spurs are the best in every respect which are produced naturally without the aid of the pruning-knife. But in addition to fruitful spurs, the trees produce a great number of superfluous wood-shoots, which, if not entirely removed, or at least so curtailed as to convert them to bearing spurs, would render the tree almost useless; in short, to effect prolific fruit-bearing, the shoots must be kept in subjection, or in the state of spurs by winter and summer pruning. A recent writer on this subject observes: 'If a tree be a free grower, all the leaders will be checked by shortening them back every year to a distance from the point of origin, which varies according to their strength; where they are very strong, the leading shoots should not be reduced more than within twelve or fifteen inches of their base; but when they are weaker, they may be cut to within nine inches. By this means the onward growth of the branch is momentarily arrested, the ascending sap is impelled into the lateral buds, some of which will be sure to grow so slow as to become productive.'

The foregoing directions comprise a view of the theoretical principles of pruning, and afford an excellent groundwork for practice; but those who are strangers to the cultivation of fruit-trees, and, as such, undertake the management of an orchard, will be surprised and perplexed at the anomalies which continually present themselves. It will then be self-evident that gardening cannot, in its routine, be learned from books; that one tree assumes a certain mode of growth; another develops in an order which has not been foreseen or contemplated; one forms its fruitful spurs spontaneously, without solicitation or the adoption of means; while another, in despite of the most rigid foreshortening, continues for years to yield nothing but leafy shoots.

Experience instructs the pruner not to expect too much, but to watch the figure which the tree affects, and the course of its supernumerary shoots. If it evince a decided tendency to form short spurs naturally at a very early period, he may prune short; but if its habit be so luxuriant as to produce wood-shoots after each pruning, it will be wise to defer the summer-cutting of the spring-shoots till the middle of July, instead of performing it at or before midsummer; and then either to snap the shoots or to cut them to a bud situated at least five inches from their base. This pruning, late as is the season, will generally cause each shoot to break its leading eye; in August, therefore, this new shoot is to be checked by nipping off its point; and finally, in September, the spring-shoot is again to be cut at the eye, below the one at which it was first pruned in July. In this way the vigour of the tree will be moderated, and several of the lower buds will probably enlarge, while the leading bud only expands into a growing shoot. If these hints be understood and acted upon, a young pruner will experimentally be taught to apply them, and thereby acquire the tact to discover the constitution of his trees individually, and to coax them into a condition of maturity. At the winter regulation, when the buds begin to swell, it will be easy to discern the fruitful eyes; and where these are discerned, the shoot projecting beyond them is entirely amputated; and this may be done with safety, for spurs,

when once fully formed, rarely break into barren shoots, though one of the eyes may do so.

Wall-training.—The circumstance of apple-trees and other kinds of fruit-trees producing fruit only on the outer parts, which are freely exposed to the sun and air, has led to numerous contrivances for exposing the inner as well as the outer stems. One method, as is well known, is the training of the tree in a flat shape against a wall—a plan also advantageous for enjoying the heat, which the wall receives and radiates against the branches. The training of trees upon a wall is a very artificial process, but by no means inimical to their healthy growth, being, on the contrary, conducive to their fertility, while it also facilitates the ripening of the fruit. Much attention is required, however, to carry out the system, and prevent the branches escaping from their constrained situation; and in pruning, the operator must keep before him the habit of the particular tree, and the form desired. One great point is to induce or preserve equilibrium in the growth of the tree, so as to give it ultimately a symmetrical form. Numerous methods of training have been introduced, but the best for general purposes, and that which has been most extensively employed in this country, is the form called



Horizontal Form.

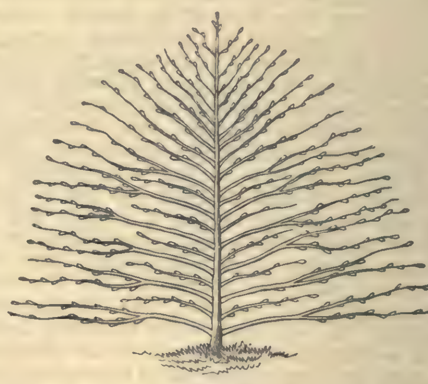
Horizontal Training, shewn in the accompanying figure; there being one principal or central stem, from which side-branches diverge at right angles, and at regular distances—about ten inches—apart. This form is best adapted for strong growing trees, such as the Ribstone pippin apple, or Gansel's Bergamot pear; but it may be so modified as to suit the more twiggy kinds. It is thus described by Dr Neill, the 'Father of Scottish Gardening:' 'In order to produce this form, the vertical shoot is, in trees of ordinary vigour, cut back every winter to within fourteen inches of the highest pair of branches; a number of shoots are produced in the beginning of each summer, out of which three are selected; one is trained in the original direction of the stem, and one on each side of it, parallel to the base of the wall. By pinching off the point of the leading shoot about midsummer, another pair may be obtained in autumn. In luxuriant trees, the vertical shoot may be left two feet in length, by which means, and by summer-pruning, four pair of branches may sometimes be added in one season. The great object at first ought to be to draw the stem upwards; when it has reached the top of the wall, it is made to divaricate into two; and the tree thus completed as to its height, is henceforth suffered to increase in breadth only.'

The next form of training we shall notice is called *Fan-training*, from the branches spreading out from a common origin; there being no prolonged main axis, as in horizontal training. The accompanying wood-cut will serve to illustrate

Fan Form.

this form better than a lengthened description. Of course this method can only be adopted successfully where there are lofty walls.

A kind of training called half-fan has been brought into notice, but is, in fact, a modification of the horizontal form, with this difference, that the branches form a more or less acute angle with the stem, which is supposed to favour the natural flow of sap. One of the forms of this method is represented below.



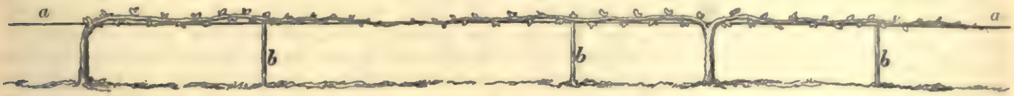
Half-fan.

Espaliers.—These are rails usually four to six feet in height, and were formerly made of upright and cross bars of wood, but now more generally formed of malleable or galvanised iron. To these the trees are trained as on a wall, with this difference, that instead of being nailed, the branches are usually tied; the fastenings are tar-twine or strips of bast. The situation of espaliers is generally parallel with the sides of walks, having a border of same width on the walk between, occupied by flowers, strawberries, or small growing culinary vegetables; and if the trees be carefully trained, they have a neat effect. Care must be taken that they do not prevent the sun and air from reaching the kitchen vegetables. When properly managed and well exposed, espalier-trees 'generally produce excellent fruit, the sun and air having access to both sides of the tree; they

commonly afford abundant crops, and the fruit is not apt to be shaken by high winds. Further, they tend to hide the crops of culinary vegetables from the eye, and to render the kitchen-garden as pleasant as an avenue in the shrubbery.'

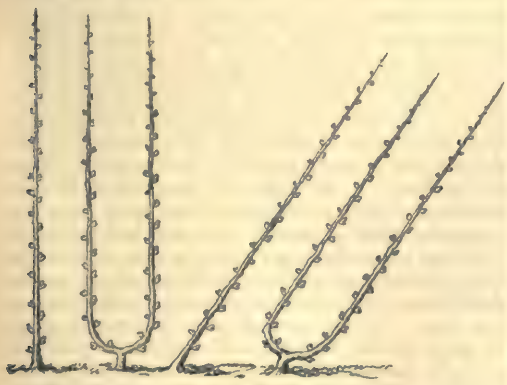
Espaliers are not necessarily confined to the hedgelike form in which they usually appear. They may be made with a quarter-arch-like curve, covering the border between and the walk, thus rendering it highly suitable for the growth of ferns and other shade-loving plants. Or, if erected near to, and arched over a walk, at a height of eight to nine feet, it will be formed into a cool-shaded summer promenade. In some, the trees are trained on inclined rails, over sloping banks of earth; others in a horizontal tabular form; while some trees are made to assume the form of cups, vases, &c. When made of malleable iron, with good strong posts at the ends, the standards need not be closer than eight or nine feet; and the horizontal wires may be about nine inches apart.

Cordon is a French mode of training now becoming popular among British cultivators. The term is strictly applicable to a tree having only one fruit spur-bearing stem and no lateral branches. In practice, however, such are termed single or simple cordons; while those having two such stems are termed double or bilateral, and sometimes U-shaped cordons. They are further distinguished as being horizontal, vertical, and diagonal.



Simple Horizontal Cordon. Double Horizontal Cordon.

The horizontal cordons are usually trained upon tightly strained wires, *a*, *a*, supported upon iron uprights, *b*, *b*, *b*, about a foot above the surface of the soil. They form excellent edgings for kitchen-garden walks; are highly suitable for very low walls, such as the fronts of hot-houses; as also for covering steep sloping banks, and fruit-tree borders, where the growth of soil-exhausting flowers or vegetables is objectionable. When joined together by splice-grafting at their meetings, continuous cordons of any length may be formed. The apple is particularly suitable for horizontal cordon training.



Vertical Cordons. Diagonal Cordons.

Vertical and diagonal cordons allow of growing many kinds on a given length of wall, and admit of covering wall-faces both quickly and regularly. The first mode is, however, only suitable for gables of houses and other elevated structures; and the distances between the plants need not be more than from 15 to 18 inches for single, and of course twice as much for double cordons. Diagonal cordons may be formed at any angle between vertical and 45°. The latter slope is that most agreeable to the eye; but, whatever may be the angle of incline fixed upon, the distance of the plants apart should be such as to allow of their transverse distances on the wall-surface being also from 15 to 18 inches.

The Pear.

The pear-tree, like the apple, is found in a wild state in all parts of Europe, and has been similarly domesticated and improved into many fine varieties. It is much longer in attaining maturity than the apple-tree; and on a heavy deep dry soil, it will survive and continue fruitful for centuries. The tree may be propagated by seeds; but grafting or budding is necessary to insure good fruit.

The observations already offered respecting soil for apple-trees, apply equally to the pear. The pruning, however, is different, for the pear is a very independent growing tree, and, as a standard, will assume its own natural figure in opposition to all restraint. All branches which lash one another must be removed; but unless the pruner cut and deform his trees in his attempts to create fruitful spurs, there will seldom be a redundancy of wood. A little foreshortening or disbudding in the spring and summer may be useful; but in general, as the pear can seldom become fruitful under seven or eight years from the grafting or budding, it will be prudent to watch the gradual development of the natural spurs, and to cut back the laterals to them when formed, and not before. Mr Knight pruned very little, shortening the main shoots occasionally, not sooner than July. He says: 'I would recommend the knife to be little used upon the young pear-trees, particularly upon the horizontal branches. As a general rule for pruning trees that are to be kept low in gardens, I recommend the upright shoots to be shortened about the beginning of July.' Cordon wall-training is particularly suitable for the pear.

Many varieties of pear are enumerated in catalogues, all differing from each other in their qualities, time of ripening, or other particulars. Among the finest sorts may be mentioned the Jargonelle, Marie Louise, Beurré de Capiaumont, Louise Bonne, Napoleon, Colmar, Conseiller de la Cour, Bonchrétien, St Germain, Rousselet, Beurré Diel, Glout Morceau, Easter Beurré, and Beurré Rance. The word *beurré*, which

here occurs several times, is from the French word for butter; and that and the other names shew how much we are indebted to our continental neighbours for perfecting this delicious fruit. The summer, autumn, and winter Bergamots are not excelled for rich muskiness of flavour. The pear requires a warmer climate than the apple; hence some of the finer sorts, which grow well as standards in the south of England, will require a wall and shelter in northern or more keen situations. Any sorts worth cultivating should have a rich aromatic flavour, and be either of the melting kind (*beurré*), or firm and crisp, like the winter Bergamots.

Orchards.

An orchard is a piece of ground specially devoted to the rearing of fruit-trees, principally apples and pears, and is frequently an appendage to the English farm and manor house. It should be a well-fenced inclosure, and if there be room for choice, its situation ought to be on the side of a dry knoll sloping to the south; the best soil is a fresh sandy loam, of eighteen inches in depth or upwards, reposing on a subsoil of dry gravel or rock. If the ground be wet, it must be thoroughly drained in the first place, as no fruit-tree can answer its purpose if the soil be otherwise than dry.

Shelter is necessary to orchards against the north and easterly spring winds, as well as against the autumnal south-west winds. This is best obtained in the former by forest-trees, and in the latter by high hedges, shrubbery, or dwarfish-growing trees. Winds from any other quarter need not be so much dreaded. Sheltering hills at some distance are advantageous; but it must always be kept in view that a free exposure to light and air is very necessary. Many orchards are almost barren, and the trees covered with lichen, from their being too much sheltered, and deprived of a free current of air.

If an orchard is a pasture for sheep, cows, or other cattle, the trees to be planted in it must be standards—that is, trees trained with a clear stem six or seven feet high, from the top of which the branches diverge, out of the reach of cattle. Sometimes the stocks are first planted, and when fairly established, are *worked*—that is, grafted or budded at the desired height.

If an orchard is to be formed out of an arable field, the ground may be prepared by the plough, laid into bands or ridges of eight yards wide, lying south and north, the trees to occupy the middle or crown of each ridge, in right lines, five, six, or eight yards asunder; and the whole area surrounded by a hawthorn hedge. When the trees are planted—which may be at any time from the end of October till April—the ground may be laid down in the spring with a crop of barley or oats, grass and clover seeds, and so remain.

If an orchard is to be formed in a grass-field, the ground is drained, if necessary, and inclosed with a hedge and ditch as above. The trees are either planted in trenched pits or in trenched borders—that is, borders six feet wide are traced south and north, and regularly trenched fifteen inches deep, the turf being turned to the bottom. Along the middle of these borders the trees are put in at the distances already mentioned. This done, the broken ground is sown down with grass-seeds, and the trees staked and protected against cattle, if they are in any danger. The pits, six feet in diameter, are trenched and planted in like manner. In planting the trees, each should be set on a little mound of the finest of the soil, on which the roots should be regularly spread, and kept near the surface; the uppermost fringe of roots being just under the turf, but no deeper; and they should be encouraged to take a horizontal rather than a downward direction. Orchards planted in either of these methods answer very well, if care is taken of the trees till they are fairly established, and can protect themselves.

The fruits chosen for such orchards are apples, pears, plums, and cherries, and of these, such varieties as are known to thrive, and are most fruitful in the neighbourhood; for all fruits are not equally adapted to the same locality, and this is a point deserving the serious consideration of the planter. Orchards of this kind are planted chiefly with a view to the service of a family, any redundance being sent to market or sold on the trees to the fruitmonger; but when fruit-trees are planted as a special source of profit, a very different plan requires to be followed.

From two to twenty acres or more of suitable land, with a proper exposure, are fixed on; the whole is trenched fifteen inches deep, and thoroughly drained, if necessary. The surface is levelled, and laid into beds 12 to 18 feet wide, ranging south and north; along the middle of these the trees are planted, and the intervals are occupied by two or three rows of small fruits, such as gooseberries, currants, or raspberries. Some of the intervals may have a row of filberts introduced, which, when kept as low bushes, are as profitable as any other kind of orchard-fruit. Such an orchard is intended to be a perfect thicket of fruit-trees. When the rows are 12 feet apart, only two intermediate rows of bushes should be planted, and the trees must be kept as dwarfs, trained in either the *bush* or *conical forms*. Of course the sorts which are naturally of a dwarfish habit are preferred; and if not dwarfish by nature, they must be made so by art—that is, branch and root pruning. The bush-form is obtained by encouraging the lateral growth of the branches, and stopping those which have a tendency to grow upright—the branches being so disposed that they may aggregately form a rotund, compact, but not overcrowded head, shading a circle twelve or fourteen feet in diameter, more or less, according to the fruitfulness or individual strength and habit of the tree. In the conical form, the centre shoot or stem should be as nearly upright as possible, and the lateral or side branches arranged so that the lowest extend farthest from the stem, the others gradually decreasing in length upwards; so that the outline of the tree forms a cone, having the termination of the centre shoot as its apex. In height, the cone may be from twice to thrice its width of base. Both the dwarf-bush and conical forms secure the fruit in a great measure from being shaken off by autumnal gales; and the latter has the further advantage of admitting more light and air to the under-growing fruit-bushes. In extensive orchards, the trees are usually left pretty much to their natural habits of growth; they should, however, be so far pruned when young as to give them evenly balanced, conically headed forms. The distances for such should be 18 feet apart, which will give space for three intermediate

rows of bushes. And if occasional rows of high-growing hardy kinds are planted at double thickness, such as the green and red Fullwood apples, and the Hessel pear, they will greatly protect the others from the hurtful effects of east and north-easterly spring winds. A mulching of half-decayed litter-dung may be spread under the trees when planted, and hoed in during next winter. Strawberries and culinary vegetables may be introduced when the trees and bushes are young, but the ground must not be exhausted by surface-cropping.

In Herefordshire, Devonshire, and adjoining districts of England, orchards are maintained principally for manufacturing a beverage from their produce. *Cider* is the liquor made from apples; the trees in most estimation for the purpose being the New Foxwhelp, the Wilding, the Cherry Pearmain, and the Yellow and Red Norman. When the ripened apples have been shaken from the trees, they are allowed to remain in heaps for a month or so on the ground, to become mellow; after which the process of manufacture into cider commences. *Perry*, or the liquor from pears, is also a pleasant and wholesome beverage, and in some instances almost approaches the quality of sparkling champagne. The most austere varieties of the pear, unfit for the table, answer best for this purpose; and a mixture of the wild pear with the cultivated sorts makes a peculiarly fine liquor.

Quince and Medlar.

These two fruits are more botanical curiosities than useful inhabitants of the British fruit-garden.

The *Quince* is classed by botanists with the apple and pear, and these are often grafted on quince-stocks, which confirms their consanguinity. It is said to be a native of Eastern Europe, and to grow wild on the banks of the Danube. It was introduced into Britain from the isle of Candia, but is not much used—the fruit in its raw state having a peculiar disagreeable smell and an austere taste. It is sometimes employed to give flavour to apples in pies and tarts, and is occasionally made into a marmalade, which is much used in the south of France, where the quince is extensively cultivated. The *Medlar* is also a native of South-eastern Europe. It has considerable flavour, but this is seldom developed, even in its ripe state, on the tree, and the fruit is therefore gathered and laid aside until it begins to change or decay, and then only is it fit to be eaten, or made into jelly.

Peach and Nectarine.

Both are natives of the East, introduced from Persia in the year 1562, and extensively cultivated since that period. Each exhibits two leading sub-varieties—namely, those in which the stone parts freely from the pulp, or *free-stones;* and those with flesh adhering to the stone, and therefore termed *cling-stones.*

The peach and nectarine (*Amygdalus Persica*) can be raised by sowing the stones, and excellent varieties have been so obtained; but as there is no certainty of what a seedling may ultimately become, it is not prudent to trust to this mode of propagation. Budding must therefore be resorted to. The peach and nectarine are seldom grafted; it is usual to select buds of trees that are approved bearers and of fertile habits, and to insert them into young vigorous stocks of the plum or almond. Nurserymen raise their trees in this way, preferring the plum-stock; the operation is performed late in July or early in August.

The buds swell, but remain torpid till the spring of the following year, at which time the head of each budded tree is cut back to an inch above the inserted bud, which then expands, and forms one or more shoots; in general, the nurseryman prunes and trains them into form during the two succeeding years, when they are sold as trained trees. Either horizontal, fan, or cordon training—as already described under the apple—may be adopted for the peach and nectarine, which must always be grown on a sheltered sunny wall.

The peach and nectarine produce their fruit upon the spring-wood of the previous year, and occasionally, also, if the habit of the tree be very vigorous, upon secondary shoots from that wood; but this is by no means desirable under ordinary circumstances, for it proves that the tree is too luxuriant in young wood, which, being developed after midsummer, can scarcely become duly mature. A tree cannot be expected to produce or support a crop of fruit in a period short of four or five years from the budding; but during that period, except in cordon-training, the art of the gardener should be employed to lay in six or more regular branches to the right and left, which will form the skeleton or figure of the tree, and remain the permanent supporters of the young bearing-wood. In the fan-method of training, secondary fruitful shoots are permitted to form at the under as well as the upper sides of these main branches; but in horizontal training, the fertile secondaries are led off from the upper sides only; all those which break from the front, or from the back next the wall, or from the under side, are obliterated as they appear, either by pinching them off with the finger and thumb, or by amputation with a sharp knife. The quantity of wood to be retained, year after year, so as to obtain a regularly increasing proportion of fruit, without redundant wood, is chiefly regulated by the judicious use of the knife, and by disbudding.

We will suppose the example of a tree trained in the nursery during two years, then planted in October against a wall fronting the south or south-east. The shoots which form the bases of the permanent branches are to be nailed, as they advance, in the most regular order, leaving them at their full length till February of the second year, when the strength and condition of the tree are to be consulted. As a first rule, we are taught, and experience sanctions the rule, 'that every shoot is to be shortened in proportion to its strength, by pruning to the point where the wood is firm and well ripened, by which all the pithy wood is

removed, causing a supply of that which is better ripened for the ensuing year.' But in order to facilitate the ripening of the wood, it must be trained thin, retaining those shoots only that may be required for the ensuing year. After two years' growth in a good soil, we may reasonably expect that six or eight permanent shoots, a yard or four feet in length, will be formed and trained in, on each hand, and that all these branches are furnished with three or more secondaries, laid in at nearly equal distances from one another, and which, by the end of June, may be a foot or more in length. The tree will continue to grow till the end of August; but disbudding must be effected repeatedly, so as to leave it in the form and condition just described. It has then become a bearing-tree, which condition implies a series of strong woody branches of two, three, or more years old, that have produced other shoots in the spring, which, when ripe, are of a deep reddish brown tint on the sunny side. These latter are the fruitful shoots, and they never bear twice; but if neglected, run on to an uncertain length, sending forth other weak laterals, which might indeed bear a little fruit, but such as could never compensate for the ruin, or at least disfiguration of the tree. It is a maxim among good pruners, that a peach-tree should be *green* throughout or all over—that is, every space, even close to the main stem, has one or more leafy and fertile shoots. This maxim would be violated in two seasons, were all the shoots permitted to extend themselves.

The bearing-shoots, therefore, must be shortened to twelve or fourteen inches, if strong; and the weaker to eight or ten inches, or even to half that length, if very slender. The pruner should cut sloping from behind. In furnishing a tree, it is not needful to cut away the wood-shoots as useless; because by pruning back to an eye seated rather low on the shoot, two good fertile shoots may be provided in lieu of a barren one. A single sharp-pointed eye is the origin of a wood-shoot; the blossom-bud is more bulky and rounded; but by deferring the winter regulation till late in February, the condition of the two will be no longer doubtful.

When it has once been so pruned, the leading branch will break its extreme bud, which will thus elongate that branch; and the fruitful laterals will also develop several minor shoots. It is from the last that a selection must be made to effect two objects of the greatest importance. The first is to attract the sap along the entire shoot, in order to nourish the young fruit upon it; and this will require that the shoot at the extreme point, or at least one beyond the uppermost fruit, be permitted to extend itself, and be nailed securely to the wall, when it shall have acquired some strength and toughness. The second object is, to provide a shoot to succeed the one now bearing fruit; and in doing this, the lowest should be selected, because it will, by its situation, replace the present shoot in a manner most conformable with the gardener's maxim before adduced, and tend to keep the tree compact and fertile. A third shoot ought also to be retained, to guard against emergency or accident; all the others should be removed by disbudding early in May. In July also, a general regulation must take place; when, by removing useless shoots, and nailing those retained, the fruit will be duly exposed to the sun's rays. Thus the growth of shoots and fruit proceeds; and if regularity and order be maintained, the tree will, year after year, elongate, and add branch to branch, retaining complete verdure throughout.

In the thinning of the fruit of peaches and nectarines, and indeed any other drupaceous fruit, it is necessary to proceed with caution, as it is apt to fall off after having attained a considerable size. In order, therefore, to secure a crop, it will be the best way to thin them at three separate times: the first, as soon as the fruit is of the size of a hazel-nut; the second, when of the size of a small walnut; and the third, as soon as the stone has become hardened; after this, it rarely happens that either peach or nectarine falls off before it is matured.

Peach-trees are liable to be molested by insects and mildew; the former are usually species of Aphis, commonly called *green-fly*. In some cases the trees attacked suffer to an extraordinary degree, insomuch that the crop dwindles and the growth of the trees is checked—three or four distinct broods succeeding each other. Fumigation and washing with tobacco-water are the only remedies; and dusting over the injured leaves with sulphur destroys the mildew.

With respect to soil and preparation of border, what we have said respecting the *apple* applies strictly to the peach. As wall-peaches must have a border, we can devise no plan more effectual or simple than that of clearing out a space of the required length, of eight to twelve feet in breadth, the depth of soil at the wall to be twenty inches, sloping to fifteen inches—making a fall of five inches from back to front. The bottom of the bed being properly prepared, the bed itself should consist of the rich but not clayey loam and turf of a common or pasture, having in it no manure whatever. The trees may indeed be top-dressed every winter with litter manure a yard or more round the boles, and so deep as to protect their roots from frost. It will also be a great preventive of drought in summer; and of this any one may satisfy himself by raising the mulch in the very driest weather, when the soil under it will be seen black and moist, though in other parts it be parched to aridity. The fruit is said to be one month accelerated, and its value proportionably enhanced, by growing a tree in a glass-covered pit of twenty-four feet long, sixty inches deep at the back wall, and thirty inches at the front. The lights will thus obtain a sufficient slope, if their length be seven feet. Hundreds of fine fruit can be produced in July or August by one tree; but great watchfulness will be required about the period of blooming, to check the ravages of the aphides in their earliest approaches; by three days' neglect, we have seen the destruction of a crop, and the ruin of all the bearing-wood of the year, in despite of every usual application.

Selection of a few of the finest Peaches.

*Bellegarde, or Galande.	*Noblesse.
*Chancellor.	Royal George.
Late Admirable.	Rosanna, or Yellow Alberge.

Nectarines.

*Elruge, or Claremont.	*Violet Hative.
Fairchild's Early.	Early Newington.

The trees marked thus (*) are suitable to the Highlands of Scotland.

Some interesting details have been given by Mr H. Bailey (*Gard. Chron.* April 4, 1857) of the

system of peach-culture adopted at Montreuil, the village celebrated for producing fine fruit for the supply of the Paris market. The walls are eight or ten feet high, and white, being coated with plaster; the soil, a brown calcareous loam, resting on limestone rock, and therefore well drained, which is essential to peach-culture. Large heaps of the sweepings of the streets of Paris were lying in the lanes, ready to enrich the peach-borders; but the point we wish particularly to call attention to is, that the walls on which the trees are trained have a broad projecting eave of thatch, which is made still wider during the prevalence of spring frosts. In England, and especially in Scotland, our wall-fruits suffer so much from spring frosts, that any hints on this subject are valuable. In some of our best gardens, movable canvas screens are employed; and by means of these, combined with the Montreuil coping, we may almost effectually guard against all such injuries.

The Apricot.

The apricot (*Prunus Armeniaca*) is a native of Caucasus and China. It partakes of the habits of the plum and peach. It is multiplied by budding, either upon the common plum or the mussel plum. Lindley says that it is usual to bud the *Moor-park* upon the former; but he is persuaded that the tree would be better, and endure longer, were it budded upon the mussel; and if he be correct in this, we may safely assert that all the best apricots will succeed upon that stock without having recourse to any other. The season of budding is comprised between the third week of July and the 16th of August, and showery weather is propitious. The buds should be selected from shoots of the spring-wood; and in taking them off, a piece of bark one inch and a half long should be retained, from which the strip of wood it contains ought to detach itself freely, without bringing with it the eye of the bud. This eye or point is a vital organ, without which a bud cannot grow. This remark applies to every kind of bud, whether it be that of the apple, pear, peach, or any of their kindred; or of any ornamental tree or shrub which admits of being thus propagated.

The best varieties of apricot are—1. Breda, a very rich juicy fruit; 2. Moor-park, of high flavour, and also pretty large; 3. The Hemskirk, similar in quality, and, in some situations, a freer grower than the last; 4. Royal, a French sort, earlier than Moor-park; 5. The Roman, hardy, and an abundant bearer, but its fruit is fit only for preserving.

As to pruning and training, when the figure of the tree is formed by having three or four branches proceeding from a main stem, each is shortened, soon after the leaves fall, to six inches, in order to obtain new branches. These are secured to the wall in May or June, at five or six inches' distance from one another, removing all supernumeraries. At the second winter-pruning, the leading shoots may be cut back to ten inches, the others growing upon them to six inches, more or less, as position and strength indicate. In May or June following, more wood is laid in from each branch; and thus, by disbudding and winter-shortening, a regularly formed head is obtained, upon the shoots of which short fruitful spurs are duly and progressively developed. In all winter-prunings and curtailments, the longest shoot that is retained ought not to exceed eighteen inches in length; thence diminishing, according to the strength of each, to nine, or even six inches.

The Plum.

The common sloe of Britain may be cited as an example of the genus *Prunus;* but those rich and luscious fruits which have been so long cultivated throughout Europe are of Eastern origin, being varieties of *P. domestica*. Plums are propagated by budding upon the common plum-stock, or on the sloe; and under favourable circumstances, the buds will produce vigorous shoots, standard high the first year. Open standards require little attention; they should be divested of all the superfluous shoots by pruning them out close to their origin, just before the season of spring-growth. But wall-trees and espaliers are to be treated as espalier pear-trees—that is, by training them with a central stem, and a series of horizontal branches proceeding from it on each side, nine inches apart. These branches are not to be shortened; and the spurs which form naturally upon them are to be kept short and compact as they advance in length. Artificial spurs may be obtained by July foreshortening; but as fertility is promoted by whatever checks the luxuriance of the wood, it will, we think, be preferable to train in the supernumerary laterals, depressing them below the horizontal level till some natural spurs are formed near their origin, and then to cut the shoots back to the lowest spur.

Plums ripen from July till November. Of the earlier dessert-plums, the July Green Gage, Early Mirabelle, and St Etienne; of intermediate kinds, the Green Gage, Victoria, Lawsons' Golden Gage, Magnum Bonum, and Woolston Black, are general favourites; while River's Late, Reine Claude de Bavay, Blue Imperatrice, and Coe's Golden Drop, are indispensable late sorts, the last keeping in a well-ordered fruit-house till Christmas. The Damson, Winesour, Bullace, and Cherry plums excel most of the finer-flavoured sorts for making preserves; and several kinds which shrivel without losing flavour in drying, such as the Shropshire Damson, Red Magnum, Quetsche, Semiana, and White Perdrigon, form the well-known *prunes* of the fruiterer.

The Cherry.

The cherry-tree, or *Cerasus*, has been known as a cultivated tree for at least three centuries; orchards, the produce of which was sold at a high price in the year 1540, existing to a large extent in Kent. This circumstance conferred the name of Kentish cherry on that peculiar kind. There are between 200 or 300 varieties, among which the best for general cultivation are the Kentish, the May-duke, Bigarreau, White-heart, Mammoth, and Morello. All may be grown as standards, but they produce larger fruit when trained against a wall.

Standard trees form their own spurs, and require only a little thinning out of superfluous branches; but wall-trees must be treated as the apricot and plum, avoiding, however, to shorten the leading branches. The Morello requires a somewhat different treatment, because it not only bears on spurs, but, like the peach, on young wood of the last spring. Mr Rogers offers some remarks, which are

deserving of attention. In the gardens of which he had the charge, 'a north wall ten feet high had a border twelve feet wide, and very shallow, reposing on loose or rubble rock. The soil was a dark hazelly loam, of rather inferior quality : the roots were very near the surface, those nearest the stem actually above it. Five trees were originally planted, but subsequently the second and fourth were removed, leaving the centre tree at thirty-two feet from the end ones. Even at this distance the branches met; and in their progress, being kept very thin of leaf-bearing wood, the crops were magnificent.' The trees were simply planted on the natural surface of unprepared ground, without any manure or deep trenching. 'Neither was this border ever dug with spades, but slightly stirred with blunt forks, and having a little well-rotted horse-dung bestowed every second or third year. There cannot be a more mistaken notion and injurious practice than overloading and poisoning the fruit-borders with rich dung. In the early training of the Morello, the knife should be used freely, to gain a sufficient number of leading branches—thinning out the laterals, but never shortening them.'

The cherry-tree grows to a large size, and its wood is highly valued by turners and musical-instrument makers, from its suitableness for being bored and formed into smooth tubes; in the luxurious East, it is much used for the tubes of tobacco-pipes. The fruit of the cherry seems less impaired by growing in a wild state than other garden-fruits. In Scotland, the wild cherries, called *geans*, are small, but of fine flavour; and in Germany, the favourite liquor, *kirschwasser*, is distilled from the juice of this species of fruit. The liquor called *cherry-brandy* is made by putting the best black varieties in brandy. *Noyeau* is a liquor flavoured by the kernels of the *C. occidentalis;* and a large black cherry is employed in the manufacture of the *ratafia* of Grenoble. The *maraschino* of Zara is made from the Marascha cherry cultivated in Dalmatia.

The Currant.

The currants are natives of Britain. They prosper only in cool climates, and they are somewhat arbitrary in their choice of a situation, even in our own moist country; they grow to an astonishing perfection in the rich moist vales of the middle counties, but the berries dwindle in hot and arid situations. Manure can be advantageously and freely applied as a top-dressing in November, to remain on the surface till after the pruning in February, when it should be lightly forked into the soil without disturbing the roots.

The following are the most esteemed sorts in general cultivation: Common red, red Dutch, Raby Castle, cherry, Knight's sweet red, champagne, common white, Dutch white, Wilmott's cut-leaved white, common black, and black Naples.

Mr Knight raised three or four hundred bushes from seeds in the course of his scientific experiments upon crossings, but of these very few excelled their parents. One of them, the red crystal, is superior in all respects. We have also raised currants from seeds, and have thus been instructed that seven or more years elapse ere the plants become fruitful, and therefore that propagation by cuttings is greatly preferable. Take cuttings of the young spring-wood, with a small heel of the older wood attached to it; divest it of all the buds excepting five of the uppermost and those of the heel; dibble holes six inches deep in a shady bed or border, and fix a cutting firmly in each hole, by pressure and watering. They succeed perfectly if planted in August, provided they be kept moist and entirely shaded, or in a north aspect; but the season extends thence to the beginning of March. The soil should be rich and light. Cuttings may be placed at first where they are intended to remain, or they may be transplanted after they become rooted plants, cutting away all but the upper whorl of roots: in either case, cut back to two or three buds the shoots made the first spring, and subsequently prune so as to make the bush broadly conical in form, without any of the branches being too crowded; which is preferable to the old open-hearted or inverted bell shape.

Prune red and white currants for fruit just after the buds begin to swell—never before February, or the birds will reduce the expected crop; and in pruning, shorten all the leaders and cut in the laterals, till the bushes appear like deformed masses of scrubby twigs. By these shortenings, the bushes progress somewhat slowly, but the fruit is produced in massive clusters from the numerous spurs. If the white sorts are matted over when ripe, the berries will remain plump and good till February or March. The black currant requires a more moist and cool site than the preceding, and that the wood be kept young, but never shortened or spurred. Whatever shoots become black and scaly must be cut entirely out, leaving those bearing branches only which are of a delicate brown colour.

The Gooseberry.

This universally known shrub is a native of Britain, and easily cultivated; it is indeed so hardy, and suitable for even keen climates, that remarkably little fostering is required to keep it in perfection; but it will not succeed in warm countries, its latitudinal range being in reality very limited. After a long course of culture, there are now hundreds of varieties of gooseberries; still, the kinds which keep their place in public estimation are few in number. The following are some of the leading sorts:—*Reds:* Kean's Seedling, Leigh's Rifleman, Boardman's British Crown, Red Warrington. *Whites:* Taylor's Bright Venus, Wellington's Glory, Saunder's Cheshire Lass, Woodward's Whitesmith, Cook's White Eagle, White Warrington. *Greens:* Parkinson's Laurel, large smooth green, Collier's Jolly Angler, Massey's Heart-of-oak, Edward's Jolly Tar, Hedgehog. *Yellows:* Didon's Golden Yellow, Prophet's Regulator, Prophet's Rockwood, Golden Lyon, Sulphur, Brotherton's Golden Sovereign and Pilot. The following are small, but of very good flavour:—*Reds:* Red champagne, red Turkey, rough red, Ironmonger, Nutmeg, and Rob Roy. *Whites:* White champagne, white crystal, early white, and white honey. *Greens:* Early green hairy, green gage, and green walnut. *Yellows:* Yellow champagne and rumbullion. The small red sorts ought to be preferred for preserves.

Although the gooseberry can be grown in almost any garden-soil, yet if excellence of fruit is desired, the soil must be a rich loam, not less than twelve inches deep, and resting on a well-drained,

yet cool subsoil. Apply manure freely, forking it in without disturbing the roots. The plantation should not be shaded too much by trees; for if these intercept the light, the fruit will not be large, full coloured, or high flavoured.

To propagate the gooseberry, take cuttings eight inches long, of the last spring's wood, having a small piece or heel of the older wood; they are inserted about the end of October, or in spring, to the depth of three inches. The situation should be shady, the earth rather sandy, and each cutting should be fixed firmly in the soil. It is customary to remove all the buds excepting four or five at the top, which are left to form the head, produced from one central stem. Should three or four eyes break at the upper part of a cutting, it will be desirable to remove all others lower on the stem as soon as it shall be manifest, from the vigour of growth, that there are good and sufficient roots to support them. When the head is formed, gooseberry-bushes can be spurred as directed for currants, avoiding to shorten the leading branches; or at each pruning in February a certain quantity of the last year's wood should be retained, and a corresponding portion of the two and three years' old wood cut out; thus, as it were, renewing the trees annually. Larger berries are thus obtained from strong young wood than by the spurring system.

When the fruit has fully set, the smaller berries may be removed for tarts, and the fine berries left to ripen for dessert. If the red and white Warringtons, and thick-skinned yellows, such as the Mogul, be matted over when the fruit is ripe, it will remain good till nearly Christmas.

The Raspberry.

The raspberry is a common native plant in Britain, but has been improved by culture. The choice sorts are Antwerp, Fastolf, Carter's Prolific, Northumberland Fellbasket—red summer kinds; Yellow Antwerp, light-coloured, very bristly wood, of luxuriant growth—fruit admirable in flavour, luscious—peculiarly adapted for dessert; October or double-bearing red and yellow, which are rather autumnal raspberries than strictly double bearers—still, by due and timely pruning, a second crop is frequently obtained in autumn; to which has lately been added a black-fruited race, procured by crossing the true raspberry with different kinds of bramble. The best are Autumn Black, Black Cap, Lawton, and Kittaninny.

The raspberry is propagated by suckers taken up from among those which rise in abundance around strong plants. The fruitful shoots or canes bear but once, and should always be cut down in August, to admit air and light to the young shoots of the summer; and from these suckers some should be selected to renew the stock every five or six years, changing the soil or situation. Care should also be taken to remove the disorderly suckers which rise from the wandering roots. The soil should be a light loam well manured; an occasional dressing of lime-rubbish produces fine canes and very fine fruit. The plants, if placed in rows, should stand a yard or four feet asunder. They may be supported by strong stakes; confining the bearing shoots to them, the successional shoots will rise, without interfering with the others.

Raspberries are by no means of difficult culture, and are often profitably grown in situations shaded by walls and trees, where scarcely any other crop can be raised.

The Strawberry.

The strawberry is one of the few fruits indigenous to Britain, and is found, like the bilberry and juniper, in a wild state in uncultivated spots, chiefly in woods and on tangled shrubby banks. It is likewise found in all the other northern countries of Europe, particularly in Norway. Several species, to which our finest varieties owe their origin, are found in the temperate regions of North and South America. This delicious fruit is, in short, very generally scattered over the earth, and was the delight of ancient as well as modern times. In Latin, its name is *Fragaria*, which is supposed to be significant of its fragrance.

In most parts of England strawberries are eaten alone, or dipped individually in sugar before being put into the mouth; and to suit this mode of consumption, they are brought to table with their stalks attached, which form shanks to hold by. But in Scotland they are brought to table stripped of their stalks, and eaten with a plenteous infusion of cream and sugar. 'Strawberries and cream' is, in fact, one of the grand national treats which strangers may reckon upon seeing set before them in the early weeks of July. In the neighbourhood of the large towns in Scotland there are many market-gardens deriving celebrity from their extensive strawberry grounds, and to these parties proceed from town to enjoy the fruit in perfection; that is to say, along with the richest and most delicious cream. In the vicinity of Dublin, the celebrated 'Strawberry Beds' in the same manner attract immense crowds of persons in the summer evenings, when the fruit is in its prime.

It is only in the neighbourhood of London that the successive cropping of strawberries, or the forcing of them at particular seasons, is methodically conducted on a large scale. The exceeding precariousness of the crop, from the liability to damage from rains, makes the rearing of strawberries a business of uncertain profit.

In the following selection of sorts, those most worthy of cultivation in small gardens are distinguished by an asterisk:

Alpine, red and white (for preserving).
*Black Prince.
*Carolina Superb.
Deptford Pine.
*Dr Hogg.
*Eclipse.
*Elton.
Frogmore Late Pine.
*Grove-end Scarlet.
*Highland Chief.
Ingram's Prince Arthur.
" Prince of Wales.
*Kean's Seedling.
La Constante.
Mammoth.
*Myatt's British Queen.
Oscar.
*Princess Alice.
*Prolific Hautbois.
Russian or Bush, without runners, and so well suited for edgings, red and white (for preserving).
Sir Charles Napier.
Sir Harry.
Sir Joseph Paxton.
White or Bicton Pine.
Wonderful.
Wood, red and white (for preserving).

The seasons for planting are March or September. The soil that all affect is a rich firm loam, trenched to the depth of two feet. The best and strongest-rooted runners are always to be preferred; and these should be planted at the periods above named into beds or borders recently prepared. Many persons retain their beds or rows, during an indefinite number of years, in a tolerable state of fertility; but the triennial

system appears to combine every advantage, while it avoids the two extremes of annual renewals and of protracted duration. When a bed is formed and in full bearing, it will require an annual surface-dressing of loam and manure, two parts of the former to one of the latter, early in the winter, to protect the plants and receive the new roots, which always are emitted just below the lowest leaf-stalks. In March, the old leaves ought to be all cut off, leaving the hearts untouched; and the beds should be cleared of litter by a wooden rake. Prior to the fruit becoming ripe, the mowings of a lawn or of any soft grass or straw laid over the surface of the soil, will prevent the berries from being soiled.

Triennial System of Planting.—1. A plot or border of earth being trenched, as before directed, select, after the first rains of September, a quantity of strong and well-rooted runner-plants, and with a garden fork or trowel, set them one by one, fresh from bed, in the new ground; if in single-border row, a foot apart; if in a bed, at the same distance plant from plant, but the rows two feet asunder. Fix each plant firmly, and pour water over it from the rose of a watering-pot. If a set of plants be thus merely transferred without much disturbance, and watered, few will fail. Hoe the ground occasionally; and prior to or during the first frost, sprinkle some manure over and around the plants. Suffer no blossom to expand in the following spring, but leave the plants to acquire strength. Stir the ground occasionally, and cut off all runners.

2. In the second September, prepare and complete a corresponding plantation. Manure and dress the plants during winter, and those of No. 1 for the second time; and in March trim off the old leaves, and rake the surface. Let the plants of No. 1 bear their full complement, the fruit of which ought to be early, abundant, and of first-rate quality.

3. In September of the third year, repeat the work, and thus complete the plantations. Treat this and No. 2 exactly as directed for No. 1. In the following spring, suffer No. 1 to bear a second crop, No. 2 its first crop, and obliterate the blossoms of No. 3. In September of the fourth year, dig up all the plants of No. 1, turn the ground, manure, and replant it. Thus the routine will be completed; and thus, year after year, there will be a plot progressing in one of the three stages; and if, with each approved variety, a similar routine course be adopted—and especially if a plantation be formed in the three aspects, east, south, and north, the last under a hedge or fence, to screen it from the south sun—the season of strawberries can be extended between the latter end of May and the middle of August. For the latter period, Dr Hogg and the Elton are peculiarly adapted; and they who can at that time command a supply of a fruit so fine and beautiful, will have ample cause for self-congratulation.

The Cranberry.

The common cranberry (*Oxycoccus palustris*) grows wild in upland marshes and turf-bogs both in England and Scotland, and generally over the northern parts of Europe. It is a trailing-plant, with slender shrubby shoots, which are clothed with small linear leaves; the fruit is an austere red berry, about the size of the common currant. It flourishes by the sides of little mossy rills, but not among stagnant water; hence the difficulty of making it an article of culture. The American cranberry (*O. macrocarpus*) is a larger and more rambling growing plant than the common species. Its fruit is also larger, and it can be cultivated on both dry and boggy ground. In some parts of the United States, barren wastes, meadows, and sandy bogs are converted into profitable cranberry-fields at little expense. Some cultivators plough the land previous to planting; the latter process being performed by digging holes, four feet distant each way, to receive the roots of the young plants. In three years, the whole ground is covered, and an acre in full bearing will often produce 200 bushels, which bring about one dollar per bushel.

Under the name of cranberries, the fruit of *Vaccinium Vitis Idæa* is more generally sold in most British towns than the true cranberries. The plant is an evergreen, with leaves somewhat resembling boxwood, is common on our highest mountain ranges, and forms excellent garden edgings.

The Grape Vine.

The vine (*Vitis vinifera*), from the juice of whose fruit wine is made by a process of fermentation, is a plant of Eastern origin, which, in early ages, was introduced into all the countries of Southern and Central Europe. Requiring a fine climate, it will not bear fruit in the open air in most parts of Britain; and it is only in fine seasons and in good exposures that its fruit is worth eating, even in the southern parts; in general, the grapes grown in gardens about London are small, and not presentable at table. In the north of France and Germany, they are little better, and we do not really get fine grapes of a proper size till we reach Italy or Portugal. In England, however, grapes produced in hot-houses surpass in size and flavour those grown on the open-air vines of Southern Europe.

In the wine-producing districts of the continent, the practice is to grow vines in large fields, either on plains or the sides of hills which are fully exposed to the sun. They are trained in rows, tied to stakes, and are pruned to a height of about four or five feet; on the Rhine, they seldom exceed three or four feet; and at a distance, the ground has somewhat the appearance of being covered with staked beans or peas. In Italy, the vines are trained to a greater height, and are made to cling to horizontal palings, as if from the roof of a hot-house.

To those in the southern parts of England, who desire to rear the vine in gardens and on walls, we offer the following directions: The varieties most suitable for culture are—1. The white sweet-water, with round berries, somewhat tinged with yellow, and faintly streaked with red on the sunny side. 2. The white muscadine; bunches rather loose, berries not very large, yellowish, and abounding with saccharine juice. 3. Early white Saumur, with very compact small bunches of beautifully transparent white berries, changing to amber when ripe. 4. Black cluster, with small berries between red and purple, closely packed, very sweet, and luscious in flavour. 5. Black July, with loose bunches of small, round, deep purple berries. And 6. Miller's Burgundy,

with small compact bunches of blackish-coloured berries and downy leaves.

A sound turfy loam, to the depth of eighteen inches, rendered open by small fragments of old lime-rubbish and a portion of crushed bones, will support any vine, and promote its fertility; and these materials can be introduced by degrees, first near the roots, then at a greater distance, to replace a corresponding quantity of old soil; thus little expense will be incurred, and still less labour. But if a new border be contemplated, and outlay be not considered, it will, of course, be best to complete the work in the first instance.

Vines are propagated by single eyes, by cuttings, and by layers, placed in pots when it is intended to remove the plants to borders or vineries. The soil should be a light, rich, sandy earth, or perfectly decayed manure and sand in equal parts; but those who wish to raise vines without loss of time, should plant cuttings taken from vines of known fertility, and of the yearling shoots which are themselves actually fruitful. Each should have three bold eyes on the young wood, and each should retain at its base a small piece of the previous year's wood. The season for planting is the month of March, and the method very simple. Dibble a hole from four to six inches in front of the wall or fence deep enough to receive the entire cutting. Mix together equal parts of black leaf-mould and white sand; put in the hole enough of this to raise the bottom one inch, and ram it hard with a blunt stick; then insert the cutting, and hold it firm in the centre of the hole, while that is filled brimful with the compost, which is brought into still closer contact with the shoot by watering. Make the ground quite even, and its surface level with the uppermost bud, then cover the cutting with a small hand-glass. If the ground is kept moderately moist, not two cuttings in a dozen will fail. If more than one shoot break, and attain the height of five or six inches, the stronger only should be retained, slipping the other off below ground. This shoot must grow till its point become spindling, when it should be nipped back; and all future growth should be thus stopped above its lowest leaf, as also the laterals that appear during the growth of the main shoot. Great care must be taken to keep the vine regularly nailed and secured by soft and roomy ties, to prevent accident, and the danger of being snapped by the wind.

As the aspects suitable to the vine are confined between south-east and south-west, the cuttings, if not duly supplied with water, may be droughted and perish before they become completely furnished with roots; but when once established, the main shoot will grow rapidly, and ripen their wood early. In the end of September, let each be cut down to an inch above the three lowest buds; mulch the ground around the stems and over the roots as winter approaches, and watch the spring progress of the eyes. If possible, obtain and secure two equal shoots; and if the wall or fence be from eight to ten feet high, or more, lead these shoots horizontally right and left about six inches above the soil, and secure them by shreds and nails. If the wall be six feet or under, retain but one strong shoot, and train it perpendicularly. In September, cut back according to the strength: thus, if the wood of the single rod last mentioned measure from one-third to half an inch in thickness, and the eyes be full, and from four to six inches apart, cut the shoot at the top of the fence, removing also the remains of all laterals and tendrils. The two horizontals will perhaps be rather slighter, yet if they be fully ripe, and furnished with bold eyes, they may be left three or four feet long on each side of the short main stem, but all the buds on the under side of each must be cut away; mulch the ground as before, and in March following, carefully fork in the manure.

Bearing Condition of the Vine.—The fourth spring will find the vines in a fruitful state; but, previously, the trees prepared for a dwarf-fence should be so pruned as to retain but three horizontal branches on each side of the main stems, about eighteen inches asunder, the intermediate branches being cut back to their lowest bold eye beyond the stem. This eye is designed to produce a new shoot, to take the place of the bearing-shoot, which, after the fruit is taken, must be cut away. Thus the vine will henceforward produce, year by year, two systems of branches, one of which will comprise year-old bearing-wood, the other a corresponding series of green wood, which will produce the fruit of the following year. This description would almost suffice to elucidate the habits of the vine; yet to leave no doubt on a subject which involves the entire theory of pruning, it will be understood that this tree bears its fruit solely upon the green shoots of the present year, which spring from the eyes of the pale-brown wood of the previous year. When, therefore, a vine is of age, and has acquired sufficient strength to support a crop of fruit, it will generally be wise to provide a new series of bearing-wood every year, because the fruit of new wood—in the white varieties particularly—is always superior. In this horizontal alternate system for low fences, each new branch may safely be permitted to extend itself at least two joints beyond its predecessor, always remembering to cut back, early in the autumn, to a short distance above a bold eye seated on perfectly ripe wood; for thus the tree will acquire strength and extent at the same time; and experience proves that, in ordinary circumstances, the fertility of a tree should be moderated, and kept below the supporting power.

The trees on the second system of training for high walls must be pruned in a similar manner, and upon corresponding principles. In the autumn of the third year, three out of four branches will be cut down to the lowest bold eye, and a few vertical shoots, from thirty inches to a yard apart, will remain; and these also must be pruned to a strong eye situated on mature wood. This system will furnish new bearing-wood every year, increasing in length as the power of the tree augments; while also the low horizontal stems will extend gradually in due proportion. At first, one, or at most two bunches must be permitted to remain upon each upright branch. In the fifth season, a greater crop may be taken, always, however, remembering to restrict the fertility of the vine; for, by so doing, its vegetating power will keep in the advance, till, in the end, the entire fence will be filled with vigorous branches, annually renewed, from which a very heavy crop may be gathered without tasking the vine in any degree that shall produce debility.

The spur-system of pruning back the bearing-shoot annually may occasionally be adopted with

black grapes, and not without advantage; yet the system of yearly renewal leaves the vine at the entire command of the pruner, and procures large clusters of fruit. The few remarks above offered enter little into minutiæ, but they elucidate general principles; and if applied practically, will, we believe, lead to improvement in grape-growing.

The fruit of the vine grows in clusters or bunches, as many, perhaps, as a hundred grapes in the bunch. It is not desirable that so many should cluster together, for, when numerous, they are apt to be very small, and to be so compact in the mass that those within do not ripen. Bunches with many grapes, therefore, should be thinned, by clipping out those of the smallest size, which will allow the others to grow to the proper dimensions. In very many instances, grapes grown on walls in gardens are spoiled by vermin, the interstices in the bunches being often filled with spiders' webs and insects of different kinds. All this is a result of carelessness in not keeping the walls clean, and thinning and otherwise attending to the bunches. As a preventive, let the walls in winter be limewashed, including all branches of the vines, and take some pains to remove all vermin which appear in the fruit-season.

Forcing.—Of the growing of vines in hothouses or vineries, it is not our intention to speak; but for the class of persons whom we address, the following suggestive account of a method for forcing vines in humble edifices, given by Mr M'Intosh in the *Orchard*, seems so suitable that we take leave to offer it: 'In many parts of the continent, and even, in some few instances, in this country, vines are forced in very humble edifices. The Dutch, Flemings, and Germans use pits, often not exceeding three or four feet in depth. These are sometimes heated by dung or tan being placed within them, which gives out a mild, humid heat, serviceable to the vine while the buds are breaking; and this, with the proper husbanding of the solar heat by judicious ventilation, is often found sufficient to produce ripe grapes at an early period. Other instances occur of such pits being heated by a smoke-flue, to which very moderate fires are applied. But what is most novel in these pits is, the vines being planted outside—the wood that is to produce the fruit is trained under the glass within, while the young wood for succeeding crops is allowed to grow without, where, under a brighter sunshine than we enjoy, the wood becomes perfectly ripened; and when the crop is gathered, the old wood, or that which produced fruit this year, is entirely cut out, and replaced with the young wood hitherto growing without the pit. Vines are also ripened on the continent by having glass frames placed against the wall on which they grow, about the time the fruit is half or three parts swelled, at which period those glasses are not in use which have been employed in forcing early crops of melons, salads, &c. The solar heat collected by this contrivance ripens the fruit well, and fully matures the wood for the following season.' Ground vineries, formed of small portable glazed frames, have of late years been largely recommended for cottage gardens. They are fully described in most trade horticultural periodicals and trade catalogues of the day.

The *Grape Blight* stands prominent among vine diseases, and is due to a minute fungus (*Oidium Tuckeri*), which consists of delicate cobweb-like threads, which spread over the surface of the young shoots, leaves, and fruit of the vine, decomposing its juices, and interrupting development of the tissues. Dusting with sulphur proves highly beneficial where the plantation is sufficiently small to permit of its being well done. In hot-houses, this remedy is of the greatest service, and ought to be resorted to in all cases where the disease makes its appearance.

The Fig.

The fig-tree is a delicate exotic like the grape vine, and great care is required to bring crops of the fruit to maturity in the open air. There are many kinds of the fig-tree, but the greater number are adapted to culture under glass only.

In this country, the nomenclature of figs is very unsatisfactory; but the following list embraces most of those known in cultivation. The kinds best adapted for forcing are marked with an asterisk, the others being suitable for the open wall in warm sheltered situations.

*Black Ischia.	Pregussata.
Brown Ischia.	*Lee's Perpetual, or Brown Turkey.
White Ischia.	*Early White.
Black Genoa.	*Early Violet.
Brunswick or Madonna.	*Marseilles or Figue blanche.
*Castle Kennedy.	

The best soil for fig-trees is a light fresh loam; but the chief essential to promote fertility is a hard and dry bottom of chalk, gravel, or artificial pavement; a dry substratum, and little depth of soil—that is, from one foot to eighteen inches—are therefore what the gardener must provide, if he expects to render the trees permanently fruitful.

As to culture and training, both are extremely simple. Rogers says, and very justly, 'that the knife is seldom wanted' [that is, in shortening; though, from the extreme luxuriance of the wood, it is frequently necessary to cut out many entire shoots]; 'pinching off the points of the young shoots during the months of May and June with the thumb and finger is the most effectual pruning.' Mr Knight restricted himself to compressing the points of the green shoots till the substance was felt to yield under the finger and thumb, by which pressure a check is given to luxuriance.

To secure fruit in due season, the pruner must recollect that in Italy and the south of Europe two crops of figs are produced yearly. Those large figs which are seen on fruitful trees here late in summer, are developed in spring, and would ripen early in a warm climate; but our winters check their progress, and generally destroy them. The crop which ripens in August is developed late in the preceding summer, and is extremely minute, almost invisible, in September; these figs are situated near the terminations of those green shoots which have been pinched or compressed; therefore, the large green figs should be displaced by mid-August, and then it will frequently be seen that two minute fruits form in lieu of the one; and these, if the tree be protected, will ripen at the season mentioned. As to protection, it will be proper to unnail and bend down the upper shoots, so as to bring them into moderate compass, then to pass a few straw bands among and across them, and finally to cover the whole with a mat or canvas sheet.

In April, train in, straight and regularly, all the bearing-wood; and as the trees grow, suffer the breast-wood to curve forward at its pleasure, pinching the points as directed. Not one shoot is to be cut shorter; but if the wood become redundant, branches which obscure the fruit should be removed, reserving those which will manifestly be fertile, and which can be duly trained in the following spring.

The Filbert.

The filbert is an improved variety of the common hazel-nut. Both plants are monœcious; that is, they produce male and fruitful blossoms very early in the year on the same tree, but separate from each other. As the trees are pruned—spurred, as it is termed—in autumn, care must be taken to reserve a number of catkins. The following are the methods of culture: Strong suckers, taken in autumn, are either planted in the nursery, or at once in the places where they are to remain; and trained in after-years either with conical or open heads. As the bush approaches maturity, short shoots (spurs) spring from the eyes, and are suffered to grow till the autumn, when they are cut back nearly to their origin, whilst also the leading shoots of the previous year are shortened two-thirds.

In the following spring, several small shoots arise from the base of the small branches which were cut off the preceding autumn, in consequence of the curtailment of the leading trained branches, and upon these secondary spurs the fruit may be expected; these shoots augment in number yearly, insomuch that many must be cut away. The largest are removed; the lesser remain, being more fertile in their habit. Many decay yearly; but whether they do so or not, those which have borne filberts are always cut away, and a fresh succession provided as future bearers. The leading shoot is every year shortened two-thirds or more, if the tree be weak, and the whole height of the branches must not exceed six to nine feet. In order to strengthen the tree as much as possible, the suckers of the roots are eradicated.

The Mulberry.

The mulberry is a native of Italy, introduced in 1548. The structure of its flowers and fruit is very singular; like the nut and filbert, the males are distinct from the females; the latter do not always expand at the same time as the males, and therefore are not fertilised. The black mulberry thrives best in good loam; the bed ought to be deep, and to rest on a dry sandy subsoil. The fruit sometimes fails; and on this subject Rogers observes, that fertility may depend very much on the warmth of the weather at the time of blossoming, and on the circumstance of both male and female flowers coming forth at the same time; sometimes also the male catkins drop before the fruit-blossoms expand. Williams of Pitmaston suggests 'that no tree receives more benefit from the spade and dunghill than the mulberry; it ought, therefore, to be frequently dug about the roots, and occasionally assisted with manure.' Others consider a velvety piece of turf as the best site. The mulberry seldom ripens fruit north of the central English counties; but deserves a place as an ornamental small tree, the leaves of which are useful to amateur rearers of silkworms.

The Melon.

The melon requires more care in cultivation than most amateur gardeners can bestow upon it; but of late years the introduction of heating by hot water for forcing purposes has largely displaced the old system of dungheaps, and has simplified the management of melons, and rendered them a more certain crop. They are now usually grown in low, glazed pits, having pipes of hot water flowing beneath the bed of soil, to afford bottom-heat. The trellis for training the melon-shoots should be sixteen to eighteen inches from the glass, so as to allow of seven or eight inches between it and the foliage, and permit a free circulation of air. The first sowing may be made at the end of November, the seeds being sown thinly in pans; the seedlings require great attention at this dull season; keep them near the light, and when they are sufficiently strong, prick them singly into pots, using pure loam. Early in January, prepare for planting. Melons succeed best in marly or clayey loam, and the soil must be made firm before planting, whether the plants are grown in the beds or in pots; the latter are preferred for the earliest crop. In the middle of January, the soil in the pots having become warm, the seedlings are to be planted, one in each pot. When the stem elongates, carefully tie each to a stick reaching from the pot to the trellis, and when trained along the trellis, stop them, by pinching out the point of the shoot, to induce fertility. Three fruits will be plenty to allow to swell off on each plant. Be careful to regulate the temperature and to keep the atmosphere moist, watering the soil occasionally with liquid manure. For successive crops, make three or four additional sowings at intervals of about a month. The following are some of the best varieties in cultivation at the present time: Bromhall, Golden Queen, Orion, Beechwood, Malvern Hall, Scarlet Gem, and Oulton Hybrid; the first four of which are green-fleshed, and the last three scarlet-fleshed.

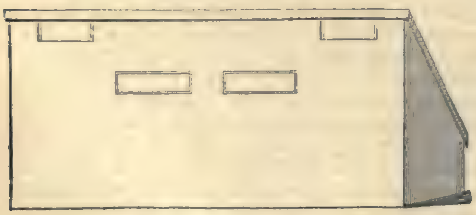
THE ORCHARD-HOUSE.

Of late years, an innovation has been made on gardening practices and prejudices by the introduction of hardy fruit-trees to pot-culture. This may at first sight seem a refinement in horticultural art which is not needed by those whom it is the chief object of these pages to instruct; but on closer examination, it will be found that the orchard-house, or, as its author, Mr Rivers, prefers to call it, the 'glass-roofed shed,' does not so much belong to the professional gardener as to the amateur and the cottager, and especially to the owner of a town-garden. It is described as a place requiring but little expense to erect, but little experience and attention to manage, and yet giving pleasing results to the suburban gardener who has but a small garden—which must be a *multum in parvo*—to the amateur with plenty of gardening taste, and but a limited income; in short, to a numerous class, with minds full of refinement and capabilities of enjoyment of horticultural pleasures, but with purses not so bountifully supplied.

The principal object of these orchard-houses is to grow small apple and pear trees, cherries, &c. in pots, to greater perfection than can be done in

the open ground, as well as to obtain grapes, &c. without the expense of vineries. By the after-explained peculiar management adopted by Mr Rivers, a crop of fruit may be realised in course of a year or two after planting, and this is a great point, inasmuch as it enables the amateur to reap a speedy harvest; for it has long been a standing adage in gardening, that 'those who plant pears plant for their heirs.'

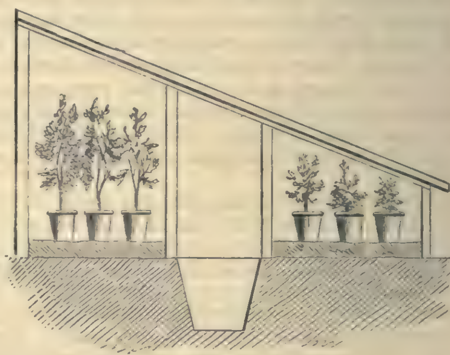
Mr Rivers thus describes his 'glass-roofed sheds:' Their length may be from ten feet to one hundred or more, according to means and space; but their breadth and height must be according to the following dimensions: Suppose the structure is to be thirty feet long; a ground-plan, thirty feet long and twelve wide, must be marked out; then ten posts or studs of oak or good yellow deal, four inches by three, and nine feet in length, must be fixed two feet in the ground firmly, the ground-ends being previously charred to the extent of two feet four inches from the bottom: this back-line of studs will thus stand seven feet in height clear from the surface. For the front-wall, ten studs four feet long must be inserted 1½ feet in the ground, so that they stand two feet six inches clear from the surface: on these studs, both at front and back, must be nailed a plate four inches by 2½ inches, on which the rafters are to rest: the studs are thus far arranged into two lines. The rafters are fourteen feet long, and four by two inches in thickness, placed with the narrow surface upwards. To spare the trouble of 'ploughing,' to make the rebate for the glass, which is great labour and waste of material, a slip of ½-inch board, ⅞ths of an inch wide, is nailed on the upper side of each rafter exactly in the centre; this will leave ⅝ths of an inch on each side for the glass to rest on—not too much for glass twenty inches wide. The rafters are now fitted on the plates at top and bottom; they must never be mortised, but let in at top by cutting out a piece, and sloped off at bottom. To receive the glass at the top of the rafters, a piece of ¾-inch deal-board, six inches wide, must be nailed along the top to the end of each rafter, so as to be even with the surface, and in this should be a groove to receive the upper end of each piece of glass; at the bottom, a piece of board, one inch thick and six inches wide, must be let in for the glass to rest on, and to carry off the water. We have thus a sloping roof, seven feet three inches high at back, and two feet nine inches in front. The glass used is 16-oz. British



Back of Orchard-house.

sheet, costing about 2½*d.* to 3*d.* per foot, and the best size of pane is twenty by twelve inches, the panes being placed crosswise, so that the rafters must be about twenty inches asunder. On and outside the back-studs, ½-inch boards must be nailed, well seasoned, so that they do not shrink too much, and painted white or stone colour. In the back-wall, sliding-shutters, 2½ feet by one foot, in grooves, must be formed for complete ventilation—two close to the roof, and two about eighteen inches from it, as in the preceding sketch.

The front has also ½-inch boards nailed on outside the studs; one of them—the upper one—to be on hinges, so as to let down; and thus air is given throughout the whole length of the house. The *building* is now completed, but its low dimensions do not admit the builder. It is therefore necessary to form a foot-path by making a trench 2½ feet wide and two feet deep in the centre of the ground-plan, which will leave a raised border on either side, four feet nine inches wide; the sides of the border may be supported by



Section of Orchard-house.

boards or brickwork. The border is to be made loose and open by a mixture of cinders, lime-rubbish, broken bricks, &c. and is enriched by manure. The pots containing the tiny fruit-trees are placed on the surface of the borders, and the foliage is thus near the glass. The roots make their way through the apertures in the bottom of the pots, which are enlarged for that purpose, and the plants thus, even in small pots, attain enough of vigour to support a crop of fruit. After the fruit is gathered, the pots are raised slightly on one side, and the protruding roots cut off with a knife; and the plants soon go to rest for the winter. It will be seen that the principle is to permit the plant to feed in the rich border by means of its protruded roots, while the fruit is being matured; while any tendency to luxuriance is checked by the removal of these roots in autumn. The trees are thus kept of convenient size and in a very healthy bearing condition. Trees adapted for this method are kept for sale in pots in all the larger nurseries; and for ample details of cultivating the different sorts, we would refer to Mr Rivers's pamphlet. This system renders the fruit-trees portable; and such trees now occasionally appear at horticultural exhibitions, while they also present a novel feature in the dessert. 'What can be more gratifying than bushes of Moor-park or peach apricots, studded with their golden fruit, arranged on the sideboard of the dining-room, or the same of peaches, nectarines, plums, cherries, and grapes?'

A Pine Forest.

ARBORICULTURE.

ARBORICULTURE, or the cultivation of trees and shrubs, is one of the most interesting and important of the rural arts. It is a branch of industry which is daily becoming a subject of great national importance, not only as regards Britain, but also her colonies and Indian empire. Science has proved that the cultivation of trees and shrubs exercises a most benign influence on the climate, and on the health and death-rate of a country, as well as on its prosperity. Hence, more attention is now being paid to the better conservation and management of forests, both at home and abroad. In this country, while agriculturists are continually carrying on a warfare of extermination with the straggling hedgerows or scattered trees that are yet common in many of the finest cultivated districts, they are fully alive to the importance of the shelter derived from trees when properly arranged on the exposed parts of their fields, or around their homesteads; while the profusion of trees and shrubs cultivated around suburban and villa residences, as well as in town squares and public parks, clearly shews how much arboriculture is an object of delight and pleasure to the people.

To cater to the public taste and requirements in this department, the utmost resources of the professional arboriculturist and landscape-gardener have been called into requisition, and at no former period has the demand been so great as during the present century. Within that period the landscape of Great Britain has undergone a complete change, and many of her bleak and barren hills and waste lands are now covered by thriving plantations. Thus, the adjoining lands have become more fertile and valuable, and the food production of the country has thereby greatly increased.

STRUCTURE AND PHYSIOLOGY OF TREES.

The general structure and physiology of plants have been explained under VEGETABLE PHYSIOLOGY and SYSTEMATIC BOTANY, to which reference may be made. The *stem*, which chiefly concerns our present subject, presents an infinite variety of modifications—assuming the form of a globular or columnar mass, as in cacti; or a pseudo-bulb, as in orchids; a hollow-jointed culm, as in grasses; a lofty branchless caudex, as in palms; or it may be twisted in a spiral manner around other plants, or form an underground rhizome, or an upright branching woody trunk, such as we see in our ordinary forest-trees. But all modifications of the stem are reducible to three well-marked forms, which differ not only in their mode of growth, but also sufficiently so in outward appearance as to render them easy of recognition. The three kinds of stem are:

1. *The Exogenous, or Outward-growing Stem*, which, in its growth, increases indefinitely in an outward direction by the annual formation of new layers of woody matter formed on the outside of

the preceding layers, but inside the bark. This kind of stem is therefore an 'outward-grower,' its thickness being yearly increased by the addition of successive concentric layers of wood.

2. *The Endogenous, or Inward-growing Stem,* whose increase takes place by the formation of new tissues towards the centre, so that the stem increases in thickness by the newly formed woody matter pushing out that previously formed, and not by the addition of new layers to the circumference.

3. *The Acrogenous, or Summit-growing Stem,* whose increase takes place principally at the summit, by the union of the bases of the leaves.

These three modifications of stems accord with other important structural peculiarities. Plants having *exogenous* stems have also an embryo with two cotyledons, or seed-leaves, and their proper leaves have usually a reticulated or netted venation; all those having *endogenous* stems have an embryo with one cotyledon, and their leaves usually have parallel venation; *acrogenous* plants, again, have no proper seed containing an embryo, being propagated by unicellular bodies called spores.

All these three classes include a certain number of *woody* stems—that is, stems whose tissue is sufficiently dense to form timber; but that of acrogenous stems (tree-ferns, &c.) is not profitably available for this purpose. Our timber-trees are therefore, in practice, reduced to the first and second classes. But we further find that endogenous stems, in their woody form (palms, &c.), are confined to warm regions of the globe, so that these also do not concern the British forester. On the other hand, woody exogenous stems are common in northern countries, and to this class belong all our timber-trees in the British Islands.

In common language, the trunk is often named the *bole;* and it is this part which affords the timber for which most trees are reared. The trunk, and also the branches, are covered with *bark,* consisting of a series of thin layers; while on the outside of all is a very thin layer of a different substance, called the *epidermis,* or cuticle. The inner layer of bark receives the name of *liber;* it was on this substance that the ancients, before the invention of printing, were accustomed to write. Within the bark is the wood, consisting chiefly of wood-cells or tubes and vascular tissues, closely interlaced. In the centre of the trunk is a small space filled with a soft substance called *pith,* from which proceed the medullary rays.

The growth of a true exogenous bole is as follows: The stem of a seedling consists at first only of cellular tissue, surrounded by an epidermis; but as soon as the leaves have expanded, some bundles of woody tubes are deposited, so as to have the appearance, in cross-section, of a dotted circle just within the skin. As the tree advances in growth, the cellular tissue in the centre becomes the pith; and rays of cells, forming the medullary rays, extend to the epidermis between the bundles of woody tissue. A membrane, or rather layer of vascular tissue, composed of spiral vessels, then forms round the pith or *medulla,* so as to separate it from the bundles of woody tissue, and the pith, in some cases, takes the form of a star with rays diverging from a centre. In the second year of a tree's life, the rays and the central pith both contract as fresh layers of woody or ligneous tissue are deposited. This process of growth of the stem by concentric layers of woody matter is continued every year till the tree is full grown. The medullary rays become changed in time into thin hard plates, which still radiate from the centre to the outer circumference of the tree, and form what is called by carpenters the *silver grain* of wood. The central pith in the meantime has diminished to a mere speck in the middle of the tree. The newly deposited layer of wood appears soft and white for the first year, and is called the *sap-wood.* The inner layers form what is called the *heart-wood* or *duramen,* which is generally hard and durable. As the layers of wood are thus distinct, and as one is deposited, in temperate climates, every year, the age of a tree may be ascertained by counting the number of concentric circles; but this rule does not always hold good. The sap-wood of regularly formed wood is usually white; but the heart-wood in many cases changes its colour to brown of various shades, dark red, or even black, according to the character of the tree. The *branches* precisely resemble the trunk in every feature of structure.

Decandolle observes that the method of reckoning the age of an exogenous stem is not liable to much error, but the inspection must be conducted with the greatest care, for the older circles become condensed into a mass, and their number can only be guessed at by measurement. His plan is as follows: 'When I have got a section of an old tree on which I can see the circles, I place a sheet of paper upon it, extending from the centre to the circumference. On this paper I mark every circle, shewing also the situation of the pith, the bark, the name of the tree, the country where it grew, and any other necessary observations. I also mark in a stronger manner the lines which indicate every *ten years,* and thus I measure their growth at *ten years'* intervals. Measuring from centre to circumference gives me the circles; doubling this, I have the diameter; and multiplying by six, I have the circumference.' He then presents a table of the periods of increase in the diameter of various trees, an inspection of which proves that every tree, after having grown rapidly when young, seems at a certain age to take a regular march of growth, and also that as trees advance in age, they still continue to form layers as thick as they previously did subsequently to the period of rapid growth. If such tables were multiplied to a sufficient extent, they would form data from which, by ascertaining the circumference of a tree, its age might be known without having recourse to the destructive process of cutting deep into the growing timber. 'If one cannot get a transverse section of a trunk, then one must seek for old specimens of each kind the date of whose planting is known, measure their circumference, deduce their average growth, and calculate from them the age of other trees of the same kind, always keeping in mind that young trees grow faster than old ones.' Decandolle cites numerous instances of trees whose ages have been ascertained according to the rule here laid down. Some of these appear to be many centuries, if not thousands of years old; and what is remarkable, still exhibit symptoms of verdure and vitality. Such calculations are apt, however, to lead to erroneous results when applied to trees grown in warm climates.

The fact that trees of such vast age continue to

bear foliage and fruit, affords indubitable proof of a very remarkable circumstance connected with the vegetable kingdom. In man and all other animals, we find an organisation and a process of life going on, which are destined to cease at a certain period. But it is otherwise with trees. They appear to possess the power of growing on for ever without exhibiting any symptoms of decay, unless from accidental or extraneous causes. 'As there is formed every year a ligneous deposit, and generally new organs, there is not among the vegetable creation place for that hardness or rigidity, that obstruction of old and permanent organs, which constitute properly the *death from age*, and, consequently, that being the case, trees can only die from accidental causes. Trees do not die from age, in the true sense of the word: they have no fixed period of existence; and, consequently, some may be found that have arrived at an extraordinary age.' But although a tree thus possesses in itself the elements of continual strength and youth, numerous causes step in to interrupt or destroy its existence; so that we are not to be surprised if the number of such vegetable patriarchs should prove exceedingly small, compared with the immense extent of the earth's surface which is covered with forest-growth.

CLASSIFICATION OF TREES.

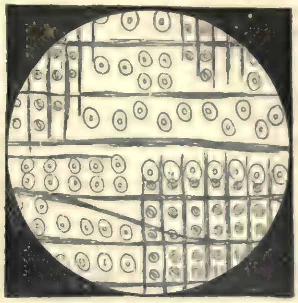
In arboriculture, trees are sometimes classified according to their uses; for example—1. Trees which produce straight timber for masts and long planks—as the various tribes of pines. 2. Trees which afford crooked timber for knees or bends in the ribs of ships, &c.—as the oak, sweet chestnut, broad-leaved elm, &c. 3. Trees which give tough pieces of timber—as the yew, holly, thorn, ash, hickory, maple, &c. 4. Hard-wood trees—as the oak, beech, plane, walnut, and box. 5. Soft-wood trees—as the poplar, large willow, lime, horse-chestnut, &c. 6. Wood or spray grown for hoops, baskets, besoms, poles, &c.—as the dwarf willows and birch. To these may be added woods of foreign growth—as rose-wood, satin-wood, and mahogany, which are employed for ornamental purposes.

According to another classification, trees are arranged as of three kinds—coniferous or resinous, hard-wooded, and soft-wooded. For the sake of clearness, we will adopt this simple arrangement, confining ourselves to a few of the more important trees which may be grown in the climate of Britain.

1. Coniferous Trees.

The obvious distinction of these trees is the production of cones containing their seeds; but they present other peculiarities. Their stems are usually tall and straight, bearing symmetrically arranged side-branches; and the wood-cells or wood-tubes of which their timber is composed, exhibit under the microscope peculiar discs with a central dot—as shewn in the accompanying figure—which at all times serve to distinguish coniferous timber from that of other families of plants, whether fossil or recent, even in a charred state.

The Coniferæ are not only useful timber-trees, but are also highly ornamental, their lofty trunks and pendent branches, clothed with peculiar evergreen foliage, rendering them conspicuous and pleasing objects in the landscape, either when



Coniferous Tissue of *Wellingtonia gigantea* (260 diameters).

grown singly or in groups or plantations. On this account, the Coniferæ have of late years received much attention from those interested in the improvement of estates; while the constant succession of new and useful additions that have recently been made to the lists of species suitable for our climate, has served to heighten the interest of this family of trees.

Scotch Pine or Scots Fir (*Pinus sylvestris*).—This is a tall and generally straight tree, with few branches on the lower part of the stem, the foliage being confined to the top of the plant, and there forming a massive clump. The numerous uses to which pine-timber is applied in this and other countries are well known. The Scotch pine is indigenous to the northern parts of Europe and Western Asia, and forms vast natural forests in the Highlands of Scotland. It grows in almost any soil, provided there be not a superabundance of moisture, and is justly valued as one of our most useful timber-trees. The two leading varieties are—1. The red-wooded or native; and 2. The white-wood, Haguenau, or continental Scots fir. Both are extensively grown; but a preference is usually given to the native sort, and especially to young trees grown from seeds saved in the indigenous forests of Scotland. 'The tree assumes its most picturesque form when standing singly, with room to spread out its branches. When grown close together, the trees are found clean-stemmed, and drawn up to a great height; consequently, such trees are available for many purposes; whereas, when standing singly, the tree is generally short-stemmed, thick, and branchy. No tree, a native of Britain, can with more safety be planted out into any soil and situation, provided only that soil be a dry one.'

Weymouth Pine (*Pinus Strobus*).—The Weymouth pine produces a whitish-yellow wood, which is pretty hard, fine-grained, and easily worked; and being usually straight, this timber is much used for masts, bowsprits, &c. It was introduced into this country about the beginning of the eighteenth century, from America. Lord Weymouth was the first proprietor who planted this tree extensively in Britain. It accommodates itself to most kinds of soils, but attains greatest perfection in valleys and on river-banks, where there is an accumulation of vegetable matter; so situated, it

attains a height of from 150 to 200 feet, with a girth of stem of from 12 to 16 feet.

Corsican Pine (*Pinus Laricio*).—This tree yields a whitish resinous timber, darker towards the pith; it is coarse-grained, but easily worked, elastic, and durable, and is much used by the French in ship-building. In this country, it is not only a valuable timber-tree, but also a useful one for ornament, for it grows rapidly, and soon assumes a handsome pyramidal form. On a good light soil, it attains a height of from 100 to 130 feet, reaching maturity in the course of seventy or eighty years. It is a native of the south and east of Europe, chiefly occurring on high elevations; on Mount Etna, it grows between 4000 and 6000 feet above the sea-level, attracting attention by its huge, far-stretching roots, which creep over the rocks, and are exposed above the surface wherever the soil is shallow.

The 'Black Austrian Pine' is a variety of the Corsican Pine, having a flat spreading head. It appears to have even a greater adaptability for different soils than the normal form of the species; and the wood, which is very resinous, is much valued from its capability of resisting the effects of water, and of alternate moisture and dryness, which is even more trying for timber than constant immersion in water. So highly is this tree esteemed by many, that it is thought it may ultimately supersede the Scots fir.

Cluster Pine (*Pinus Pinaster*). — This tree affords a soft, and not very durable wood, which is chiefly employed in making boxes, &c. and is better known in France than with us. The cluster pine, however, has strong claims upon our attention, for it is capable of producing timber on soils unfit for other plants. It is a southern European species, growing along the shores of the Mediterranean, and on the Apennines, to about 2800 feet above the sea-level. On wet soils it will not grow; but wherever the soil is dry, even if exposed to the sea-breeze, it forms a handsome pyramidal tree, fifty or sixty feet in height. In France, it has been employed profitably to cover immense tracts of sand along the shore; and so far as it has been tried in similar situations in Britain, it has succeeded equally well.

Spruce Firs constitute a well-known genus (*Abies*) of the Coniferæ, and include many valuable timber and ornamental species. *Norway Spruce* (*A. excelsa*).—This tree attains great height, and furnishes white deal and spars; it is also very suitable for masts and poles of all kinds. It is now widely planted throughout Britain, particularly in the Lowlands of Scotland; and when enjoying a favourable situation, soon grows to a useful size. It is a hardy tree, and though its timber is softer and less durable than the Scotch pine, yet, from the rapidity with which it grows, and its adaptation to a soil rather damp, it is frequently preferred. In many parts of Northern Europe, it forms the principal timber, being known in the market as white deal or Christiania deal. When grown singly in a moist soil, the Norway spruce becomes a handsome tree.

The *White Spruce* (*Abies alba*) is a North American species, whose root-fibres, macerated, are used by the Canadian Indians as thread to sew their birch-bark canoes. It is associated with the *Black Spruce* (*A. nigra*), which is even a hardier species, growing in the most inclement regions. Its timber is very strong, light, and elastic, and is valuable for the yards of ships, and other purposes in which these qualities are required. The young branches yield essence of spruce, known to voyagers as an antiscorbutic.

The *Douglas Fir* (*Abies Douglasii*) is one of the most valuable and beautiful of the numerous species introduced by that devoted explorer and plant-collector. It grows rapidly, but forms a fine-grained timber, elastic, strong, free from knots, easily wrought, and capable of receiving a high polish. It forms immense forests in North-west America from 43° to 52° north latitude; the erect tapering trunks varying from 100 to 180 feet in height, and many of them nearly ten feet in girth. The tree is very ornamental, and well adapted to our climate. It is now being largely planted as a forest tree, and is gradually superseding the larch, not being liable to disease. *Menzies' Fir* (*A. Menziesii*) also produces timber of excellent quality.

The *Silver Fir*, called also the Pitch Fir (*Picea pectinata*), displays a greater depth of branches than the other firs, and becomes a majestic tree on arriving at full age. In this country, the silver firs are chiefly seen as objects of ornament on dressed ground. The quality of the silver-fir timber of British growth is rather indifferent. The Noble Silver Fir (*A. nobilis*).—This is another magnificent tree, introduced by Douglas. It is thoroughly hardy, and of tolerably rapid growth.

The Larch.—Of this valuable genus (*Larix*) there are several species grown in Britain; the more common being the *L. Europæa*, which is one of the most beautiful of this class of trees; its straight elegant stem tapering to a point, and furnished with pendulous branches ornamented with delicate drooping spray. In many parts of the country, it has gradually superseded the common fir, over which it possesses a great superiority in point of ornamental effect; but of late years, the 'dry-rot in larch' (as it is called) has served to discountenance its use for many purposes. There are two varieties of the larch generally cultivated in Britain—the white and the red. The white is the variety which attains the greatest dimensions of timber, and is the sort most generally cultivated. No timber-tree at present cultivated in our woods begins to repay the expense of culture so soon as the larch does. It is a rapid-growing tree, and is well adapted for almost every country purpose. It generally sells at nearly double the price per cubic foot that Scots fir brings; and besides the price of the wood, the bark is available for tanning. The circumstances which are found favourable to the healthy development of the larch are—as to soil it is not particular, but the roots must have a constant supply of water, in order to keep the earth in which they grow in a pure state. On very arid soils, the larch never grows freely, and soon dies off with a stunted lichen-clad bole; and on flat ground, where water is liable to stagnate, though the young trees may succeed for a few years, yet they are never found to prosper, but die away as soon as the mere surface-turf is exhausted. The larch, so plentiful on the European Alps, did not find its way into Britain until the beginning of the sixteenth century, and was little known or planted as a timber-tree for more than

a century afterwards. The well-known and magnificent larches at Dunkeld, which were first sent to the Duke of Athole, were treated as tender greenhouse plants. They soon became sickly, and at length were consigned to the 'rubbish-heap' as dead. Favoured with fresh air and a showery season, they were observed to push forth new leaves, and were taken and planted out in the open air, where they continued to flourish, and are now the finest specimens in this country.

The *Cedar of Lebanon* (*Cedrus Libani*) is remarkable for its long horizontal branches, and the great mass of dark-green spicular foliage with which it is covered. It is a native of the mountains of Libanus and other high adjacent regions, where it attains great bulk, and grows to a very great age. From its solemn aspect, it forms a suitable accompaniment to ecclesiastical buildings or cemeteries, and also for sequestered glens in mountain scenery; it is equally well adapted for extensive lawns. Cedars were introduced into Britain as far back as 1683; and there are but few old country-seats that do not possess some specimens. Many majestic ones are met with in different parts; but in no situation have they thriven more prosperously than at the celebrated residence of Moor Park, in Hertfordshire.

Deodar or Sacred Cedar of India (*Cedrus Deodara*).—This is perhaps one of the most beautiful of the whole family of Coniferæ, its erect stem, and widely spreading, gracefully curved boughs, drooping at the tips, and clothed with the most beautiful green foliage. It grows on the mountains of Northern India, on heights of 10,000 or 12,000 feet. The Hindus hold it in great veneration, calling it the Tree of God. Its wood is so durable, that specimens several hundred years old have been taken from Indian temples quite sound. Although the habit of this tree differs from that of the preceding species, still it is regarded by many botanists as not specifically distinct. It has been largely planted as an ornamental tree during the last few years, being peculiarly suitable for pleasure-grounds, and especially for lawns and cemeteries.

Chili Pine (*Araucaria imbricata*).—This tree is the greatest ornament among conifers; and is now common in pleasure-grounds. The male tree is said never to exceed 40 or 50 feet in height, while the female often attains 150 feet; but all the specimens in this country are as yet comparatively young. A deep light loamy soil is the most suitable for this tree. Its wood is yellowish-white, hard and durable. It cannot be said to be *quite* hardy in Britain, for the early severity of the winter of 1856–57 browned the foliage of many specimens in different parts of the country, without, however, affecting their vitality; and during the severe winter of 1860–61, many fine specimens were completely killed.

The Wellington Tree (*Wellingtonia* (*Sequoia*) *gigantea*).—This is the great monarch of western forests, its gigantic proportions exceeding those of all other coniferous trees with which we are acquainted. It inhabits the elevated slopes of the Sierra Nevada, in latitude 38° north, longitude 120° 10′ west, at an elevation of 5000 feet above the sea-level. The trees there observed varied from 250 to 350 feet in height, and from 10 to 20 feet in diameter. One that was felled measured about 300 feet in length, with a diameter, including bark, of 29 feet 2 inches, at five feet from the ground; at eighteen feet from the ground, it was 14½ feet through; at one hundred feet from the ground, 14 feet; and at two hundred feet from the ground, 5 feet 5 inches. The trunk was perfectly solid. 'What a tree is this!' says Dr Lindley; 'of what portentous aspect, and almost fabulous antiquity! They say that the specimen felled at the junction of the Stanislau and San Antonio was above 3000 years old; that is to say, it must have been a little plant when Samson was

The Mammoth Pine (*Wellingtonia* (*Sequoia*) *gigantea*).

slaying the Philistines, or Paris running away with Helen, or Æneas carrying off good *pater Anchises* upon his filial shoulders.'

In this country, the tree is perfectly hardy, and is of rapid growth. It does well in any ordinary description of soil, but luxuriates in a good, deep, moist, loamy soil and sheltered situation. The timber is of a red colour, clean, short-fibred, light and soft, porous and brittle, non-resinous, and non-fragrant, particularly when matured.

The *Yew* (*Taxus baccata*) is more frequently grown as an ornamental than as a forest tree, and, like the cedar, it forms a plant suitable for places consecrated to solemn feeling. Its timber is very tough, and is adapted for making bows and staves, hence it is commonly ranked among hard-wooded trees. As an ornamental tree, it should be fenced round, as its foliage is highly poisonous to horses and cattle; and being evergreen, is very apt to be browsed upon during the winter.

Yews are believed to be the most ancient planted trees of Great Britain; and no doubt can exist that there are individuals of the species in England as old as the introduction of Christianity, and there is every reason to believe very much

older. It is the opinion of Decandolle, that, of all European trees, the yew is that which attains the greatest age. The following are some of the more remarkable British specimens to which the attention of the curious has been directed. Those of the ancient Abbey of Fountains, near Ripon in Yorkshire, were well known as early as 1155. Pennant says, that in 1770 they were 1214 lines in diameter, and consequently, according to Decandolle's method of computation, were more than twelve centuries old. Those of the churchyard of Crowhurst in Surrey, on Evelyn's authority, were 1287 lines in diameter. There are two remarkable yews still in the same cemetery, and if they are the same that Evelyn refers to, they must be fourteen centuries and a half old. The yew-tree at Fortingal in Perthshire, mentioned by Pennant, in 1770, and part of which still exists (1873), had a diameter of 2588 lines, and consequently we must reckon it at from twenty-six to twenty-seven centuries old. The yew of Brabourne churchyard in Kent is said to have attained the age of 3000 years; that at Hedsor in Bucks, however, surpasses all others in magnitude and antiquity; measuring above twenty-seven feet in diameter; thus indicating the enormous age of 3240 years!

2. Hard-wooded Trees.

In this class are included a large number of trees with which every one is familiar. The list embraces the oak, ash, elm, beech, chestnut, walnut, common sycamore, mountain-ash, hornbeam, false-acacia, birch, wild-cherry, laburnum, holly, box, and hawthorn. The following are the principal:

The *Oak* (*Quercus*) is the most valuable of all the timber-trees grown in Britain, not only because it is a hardy native, but for the many important purposes to which its durable timber, its astringent bark, and even its nutritious fruit, are applicable; and, moreover, for the delight which it gives to the eye in sylvan landscapes, the oak being the most picturesque tree of the forest when it has arrived at its mature age and form, and is still clad with foliage.

There are two species in our woods, natural or planted—namely, the *Q. robur*, whose acorns grow singly and with long stalks; and the *Q. sessiliflora*, whose fruit grows in clusters, with short acorn stalks. The former is said to be the old Druidical British or naval oak, though the latter is more frequently met with, especially in woods which have been planted by the hand of man. Besides these two common sorts, there are many other species and varieties, which are exotics—namely, the willow-leaved, the evergreen, ash-leaved, holly-leaved, chestnut-leaved, scarlet, white, Italian, durmast, Luccombe, the Turkey, &c.

All the species are readily raised from their acorns. The young plants are transplanted twice or thrice in the nursery; and when four or five years from the acorn, may go to their final stations. Any kind of clayey loam is suitable for the oak; but a good gravelly loam, upon a subsoil of blue ferruginous clay, produces the finest timber in the shortest time. 'The largest oaks I have ever seen,' says a writer, 'grew upon a dry sandy loam, with a free exposure to air; however, although the oak may attain its greatest dimensions under such circumstances as these, we find it growing to the size of useful timber wherever it has the advantage of a soil with a dry bottom, and not too much exposed to storms—as,

The Oak.

for instance, upon the top of a bare hill. The oak will not thrive or live long in a damp mossy soil.'

England, as well as Scotland, at one period possessed many noble and remarkable oak-trees, the remains of which are in some instances still to be seen, while in others they are only remembered in tradition.

The *Ash* (*Fraxinus excelsior*) is also a very valuable hard-wood tree, its timber being useful for many rural purposes, and particularly for implements and machines. The common ash, being prolific in ripening seed, is dispersed pretty generally over the face of the British Isles. The circumstances favourable to the healthy development of the ash are, as regards soil, a good strong loam, rather rich than otherwise, and rather moist than dry—for it does not disagree with a little moisture, provided that this moisture has free and ready escape from the roots. Being fond of shelter, it grows well in a hollow or glen, or in the interior of a large plantation.

An ash-tree is in its prime when, by free and vigorous growth, it has attained a diameter of about twenty inches; for though on rich gravelly loam it will continue to increase until it is four or five feet in diameter, it has probably begun to rot at the core long before it has arrived at that vast bulk. Therefore, in order to raise ash-timber of the most valuable description, it is necessary to sow or plant a piece of land of the above character thickly, placing the trees about two feet apart. These will rise rapidly; and as soon as they appear to be choking each other, one half of the poles may be drawn, and the rest allowed to stand till they arrive at a marketable size, which is when they are from eight to twelve inches in diameter, and from forty to sixty feet high. When *ground-ash* is of these dimensions, it is suitable for every mechanical purpose where flexibility and extreme toughness are required. From its upright habit of growth, the ash forms one of our best forest-trees; and what is especially deserving of notice, its timber is better—that is, more tough, elastic, and durable—the more rapidly it is grown.

Seed should be gathered in the autumn, and immediately sown in nursery-beds; or the sowing may be deferred till spring. As soon as the seedlings are five or six inches high, they should be rowed out to gain strength till finally transplanted. There are several varieties of the common ash, one of which is the weeping-branched, which, by grafting high on the tall stem of the common ash, forms a very ornamental weeping-tree.

The *Scotch or Wych Elm* (*Ulmus montana*), and the *English or Small-leaved Elm* (*Ulmus campestris*), of both of which species there are many varieties, are valuable timber-trees. No trees bear lopping or pruning better than the elms. In the forest, they require considerable space, as their natural habit is to throw out on every side broad spreading branches.

The *Beech* (*Fagus sylvatica*) is a native forest-tree, occurring most commonly on the chalky districts of the kingdom. When full grown, it is a beautiful and stately tree; and its timber is convertible into many kinds of domestic articles, very durable when polished by the cabinet-maker, and equally so if kept constantly under water.

Young plants are readily raised from the seed sown on beds, and covered with loose soil about an inch thick. Like other seedlings, they are, when five or six inches high, rowed out on fresh ground, till large enough to be transferred to their final stations. The beech is not at all fastidious as to soil; but a subsoil of chalk or limestone is most congenial. Few trees suffer less from mismanagement than the beech; and upon thin, poor soils, and even in high and exposed situations, no hard-wooded tree is so worthy of a place. There are several species; the white-American, the dark-purple, and the dark-leaved, are ornamental, and are propagated by grafting on the common.

At Newbattle Abbey, a few miles south from Edinburgh, there are some remarkably fine large trees, most probably planted by the monks prior to the Reformation. Professor Walker measured a beech at this place in 1789; its trunk, where thickest, was seventeen feet in girth, and the span of the branches was eighty-nine feet. He thought that it must have been planted between 1540 and 1560. It was blown down a short time before the year 1809. It contained upwards of 1000 measurable feet of timber—twenty loads, or twenty-five tons—and was with reason reckoned among the largest beeches ever grown in Scotland. Another at Taymouth, of a like size, and seemingly coeval with this, was blown down when it had reached more than sixteen feet in girth. A large beech near Oxenford Castle, in Mid-Lothian, was measured on the 6th of June 1763. At the height of three feet from the ground, its circumference was nineteen feet six inches. This fine tree was then decaying.

The *Chestnut*, or *Sweet Chestnut*, sometimes also called the *Spanish Chestnut* (*Castanea vesca*), is a splendid forest-tree, exceeding all other British plants in its huge mass of foliage; it is also valuable for its timber, which is but little inferior to the oak. In the south of Europe, it is chiefly regarded as a fruit-tree; but here, even in the south of England, in the finest summers, the fruit ripens but imperfectly. As a timber-tree, however, the Spanish chestnut deserves to be more generally planted than it has been of late years; and for a coppice or underwood plant it has no superior. For the number, the straightness, and durability of its poles, it excels all others, when a little trouble is taken to keep the growth perfectly regulated with respect to the purpose for which the crop is wanted. When timber or ornament is the object, the trees must constantly be divested of the shoots, which are apt to rise from the stem. A strong loamy gravel seems to suit this tree best; and young plants are easily raised from the nuts, dibbled in rows in the spring, and while in the nursery, kept free from bottom-shoots. The sweet chestnut requires considerable shelter, in order to permit of its full development; and should always be cut down before arriving at maturity, as the heart-wood is very liable to decay.

The *Common Walnut* (*Juglans regia*) is chiefly regarded as a fruit-tree, but it is no less valuable for its excellent timber, which, from its lightness, durability, and beauty, and the high polish it takes on, is well adapted for house-furniture, and is almost the only wood used for gun-stocks. Where its fruit is of no great value, and especially where it does not ripen, if planted among other forest-trees, it would be drawn up into a shapable single stem, as valuable as many others. Young trees are readily raised from the nuts, like the chestnut, and are similarly managed.

The *Sycamore or False-plane* (*Acer pseudo-platanus*) is a hardy native tree, and grows more quickly than most of the other hard woods. It attains a large size, and lives to a great age. It prefers a dry sandy loam, with free exposure, but may be profitably planted in almost any situation, except in damp or mossy soil.

The *Mountain Ash* (*Pyrus aucuparia*), familiarly known in Scotland as the *rowan-tree*, from its beautiful clusters of red rowans or berries, is a tree of small dimensions, but elegant form, and is grown principally for ornament. It is hardy and of easy growth in dry soils, and makes an excellent skirter or outside tree in ornamental clumps and plantations; its finely formed foliage and white blossom yielding variety in summer, and its deep red berries as striking a variety in autumn and early winter.

The *False-acacia* (*Robinia pseud-acacia*) is not only a highly ornamental, but also a valued timber-tree, when allowed to attain a proper size. Though a native of Virginia, and there called the *locust-tree*, it has been recommended as a coppice-plant for this country, on account of the very quick growth of its young shoots, which rise from roots after the stem is cut over; and for the excellent and durable quality of the poles for fencing, and particularly as props for hops, &c. But whether planted thickly for underwood, or more openly for timber, the acacia requires much attention from the pruner during the first five or six years of its growth. Young plants are raised from seeds or from layers, and thrive on any light sandy soil. The timber is highly prized by millwrights for cogs and other friction purposes.

The *Wild Cherry* or *Gean-tree* (*Prunus avium*) is a hardy native, but is seldom cultivated as a timber-tree; nor is that care bestowed upon it which it really deserves. The best specimens to be met with are those which have grown by accident in woods; but when such are felled, they are readily purchased by the cabinet-makers. The wood is very suitable for boring and for forming musical instruments. It is therefore a tree not to

be neglected by the general planter, and should have a place among others. Young plants are raised from the seeds or stones, sown thickly on a bed of good soil, either in autumn or in spring, and afterwards rowed out to receive the ordinary nursery treatment, until fit to be finally planted.

The *Hornbeam* (*Carpinus betulus*) is an inferior forest-tree; its timber, however, is remarkably tough and durable, and consequently valuable to the plough and cart wright. It is a tortuous-growing tree, unless pruned when young.

The *Birch* (*Betula alba*) is another inferior timber-tree, but useful, as a coppice-plant, for many rural purposes. It has a beautiful and elegant contour, on which account it is introduced into ornamental scenery, especially if water be in the composition. Of the common birch there are several varieties. Young plants are most conveniently raised from seeds. Wherever there are poor thin-soiled stony heights, the birch may be planted as a useful cover; its timber is readily bought up for gunpowder charcoal.

The *Holly* (*Ilex aquifolium*) is a remarkably hardy evergreen, with smooth shining leaves furnished with prickly points. It is a native of Britain, and attains a great age, but seldom reaches a large size. Its timber is white and hard, which renders it suitable for veneering and for making mathematical instruments. Different varieties are grown as ornamental shrubs. The holly hedges of Tyninghame, in East-Lothian, have long been famed, being 11 feet broad and from 18 to 25 feet high.

The *Box* (*Buxus sempervirens*) is generally grown as an evergreen shrub, but when planted out with a proper soil and climate, it attains a considerable height. *B. balearica* grows to perfection in Turkey, whence its timber is imported for use in all cases in which exceedingly fine cross grain is required. Sawn across and planed, its surface is as smooth and fine as polished metal. Box-blocks are on this account employed for wood-engraving.

3. Soft-wooded Trees.

In this section may be included the horse-chestnut, lime, alder, poplar, and willow.

The *Horse-chestnut* (*Æsculus hippocastanum*) is only valued for the beauty of its flowers and the majesty of the full-grown tree in park-scenery. The timber is very inferior. There are several other exotic species—namely, the smooth, Ohio, ruddy, and the pale-flowered, all of which are easily raised from their large nuts. They require shelter and good rich soil; they grow rapidly under these conditions, and soon form highly ornamental objects. There is a nearly allied genus called *Pavia*, or bucks-eye, the species of which have round and smooth fruit. The flowers of some of these last are magnificent, being of a glowing red, and are most conspicuous in the spring or beginning of summer. Avenues of these trees, as seen in the neighbourhood of Geneva, present a gorgeous appearance when in flower. The pavias are often propagated by being grafted upon the common horse-chestnut.

The *Lime* (*Tilia Europœa*) is a beautiful leafy tree, grown chiefly for ornament, and very suitable for avenues. There are several varieties, but as all of them require a heavy soil and sheltered situation, and their timber not being of much value, they are seldom or never introduced into the forest. The lime is the European tree which, in a given time, appears capable of acquiring the largest diameter.

The *Alder* (*Alnus glutinosa*) requires a damp bog-earth soil, and is only planted by streams, or to occupy a spot where nothing better will grow. It is most profitably kept as underwood, large poles suitable for the turner or for piles or planking for bridges, fetching a high price.

The *Poplar* (*Populus*).—There are several species—as the common black poplar (*Populus nigra*), the aspen or trembling poplar (*P. tremula*), the Lombardy poplar (*P. fastigiata*), &c. They grow rapidly, and the last-mentioned rises to a great height, but narrow in mass, so as to be very conspicuous in hedgerows and landscapes. The timber is soft, but a good deal sought after; and where undrainable spots are wished to be decorated with stately trees, no better kind can be chosen.

The *Willow* (*Salix*) is an extensive genus, comprehending those shrubby species, the osiers, used for basket-work, as well as a few species which attain to the height and character of trees, the best of which, as yielding very good timber, is the white or Huntingdon (*S. alba*). Another of the tree-willows is that elegant plant the Babylonian or weeping willow (*S. Babylonica*), which forms so suitable an accompaniment to pieces of water, whether artificial or natural. The common osier is the sort mostly cultivated for the basket-maker, and the annual crop of rods from established stools pays the owner as well as any other crop on the farm. All the kinds are easily propagated by cuttings, and require to be grown in damp soil.

REARING OF TREES.

Trees grow spontaneously in all countries in which soil and climate will permit, and, as is well known, form forests of many hundreds of miles in extent on the North American continent. Whatever be the peculiar nature of any species of tree, it appears that the dimensions and form of all are more or less affected by their relative situation. If crowded, they have a tendency to grow tall and slender; if left abundance of space, they extend in breadth. The comparative absence or presence of air and light causes this. In a forest, each tree struggles upwards; whereas the tree in open ground shoots out lateral branches nearly from the bottom of the trunk, and attains a mass of foliage.

All exposed trees have the largest roots; being liable to be blown over, they take a much firmer hold of the ground than if they were sheltered on all sides; in other words, the action of the tree, and the free air and light, induce the development of numerous branches and a large breathing apparatus of leaves, and the tree must have a corresponding mass of roots for the supply of sap.

Ornamental Plantations.

Even on the smallest possessions, a sprinkling of forest-trees in the hedges or corners of the inclosures gives a dignity to the spot which otherwise it would not possess. There cannot be a more cheerless object in a landscape than a house —however substantially built—standing naked and alone, without a sheltering tree or bush to

indicate either the taste or competence of the occupiers within. The lowliest hut, environed by two or three aged oaks or hawthorns, is an interesting spectacle, and far more delightful to the eye than the proudest palace standing bare and unaccompanied by trees.

In ornamental planting, there is much room for the display of good taste. It is now allowed by all who have studied landscape-gardening, that in the part surrounding the mansion, trees should not be dotted about at equal distances, nor in lines, neither should they be placed as blinds to the principal windows, but so arranged as to form irregular glades, diverging in as many directions from the house as is consistent with effect and propriety. These glades should always be laid out with reference to some distant interesting object, or some striking feature of the surrounding country. The offices, which are generally in the rear, or at one end of the house, should be hidden by a screen of trees and shrubs; and all eyesores, visible from the windows or elsewhere, should also be screened by plantation.

When it is intended to increase both the beauty and the value of an estate by planting, either for the personal interest of the proprietor, or with a view to that of posterity, ordinary prudence will direct him to fix on those parts which are the least valuable for agricultural purposes. The precipitous slopes of an undulating surface, where cultivation is difficult or impracticable, moist swampy hollows, or the ridges of bleak hills lying to the northward or eastward, will all be found eligible for conversion into woodland. And while such plantations yield the finest shelter and cover for game, they rapidly add to the real value of the estate.

The character of the general surface surrounding a mansion fixes the style of planting and the kinds of trees. If the surface be moderately undulating, having easy swelling knolls and gently falling hollows, without asperities of any kind, such a surface is said to be beautiful, and consequently the plantations should be beautiful also; that is, composed of trees of the finest foliage and most elegant forms. But if, on the contrary, the surrounding country be wild in character, and marked with bold and rugged features, as naked rocks or cliffs, and deep ravines or glens, then a different style of decoration must be pursued—as planting in irregular masses all the most grotesque, rugged, and sombre-tinted trees that can be selected, in order to harmonise with the natural features of the country. Scenery of this kind is said to be picturesque; and where such tracts of country are chosen for a manorial residence, and the grounds are laid out and planted by a skilful gardener, the scenery is much more interesting to the eye of taste than any other, especially if water chance to be in the composition.

Great changes occurred in the style of planting during the eighteenth century. Up to the beginning of the reign of George I. all transplanted trees were arranged in right lines, as single, double, or quadruple avenues or vistas, or as boundaries to the inclosed grounds belonging to royal or other palaces, colleges, and public buildings. But about this time it was discovered that trees in rows were rarely seen in the works of the great masters in the schools of painting: a new idea was entertained that such a disposition of trees was inadmissible, as being too stiff, formal, and not agreeable to nature; a sentence of condemnation was accordingly passed upon private avenues, and they quickly disappeared before the axe of the woodman. A few only were saved, and now comparatively few avenues are planted. Along with the avenues, the old regularly laid out terraces and flower-gardens were swept away to make room for a new style, distinguished by the prevalence of *irregularity* and *curved outlines.*

Soon after this revolution in landscape-gardening, a great many ridiculous pranks were played in obtaining *extreme* irregularity and *tortuous* lines; and some of the performers got severely handled by the satirists of the day. Kent, who began the revolution, died without having gained much reputation; but his successor, the famous 'Capability' Brown, became highly eminent, and was universally employed. He did more in altering the gardens and grounds of the country-seats of these kingdoms than any landscape-gardener before or since his time. His aim was to produce unmixed beauty by neatness and general smoothness, especially near the house; for which purpose he cleared away every obstruction, whether built or planted, in order to set the mansion fairly out upon a naked grass-plot or lawn. Even the kitchen-gardens were removed as far off as possible; and every bush, or other appearance of inequality, was shaven off, to produce the wished-for smoothness. In this proceeding he and his copyists fell into the opposite extreme; instead of beauty, *baldness* was the result; instead of intricacy, *tameness;* and instead of the embosoming shelter of surrounding groves, complete nakedness, and exposure to every wind that blows. Nevertheless, Brown had the honour of laying out many beautiful parks and gardens, which remain to this day as monuments of his good taste and judgment; but many of his immediate followers brought discredit upon his style by their very awkward and unmeaning imitations.

The severe animadversions published against the Brownian style tended to correct some of its author's most ostensible errors; and the works of Repton, Loudon, and others, have improved the style of English landscape-gardening, and brought it much nearer to the principles of real taste. The *clump* and the *belt* have been greatly modified; the first is now expanded into a less formal group, and while the latter has lost its continuity, it has been increased in depth, and its lengthened form as a boundary judiciously broken. Undergrowths, which were swept away by Brown, are again introduced; and the banks of lakes and rivers, formerly smoothed down to the water-level, are now left more abrupt, broken, and irregularly fringed with overhanging trees and aquatic shrubs and herbs.

Forest-planting.

We may begin by premising a few important points of general application. Young plants, about ten inches high, are usually procured from a nursery where they have been grown from seeds. At the time of removal they are perhaps three years old. It is important, for the sake of having good roots, that the plants while in the nursery should have been shifted twice, or at least once, previous to final removal. It is likewise important that the climate of the nursery should somewhat resemble

the climate of the part of the country to which the plants are transported. Young plants grown in a nursery near the level of the sea will have a poor chance of thriving when transferred to a mountainous high-lying district. Suitable plants being procured, it is absolutely necessary that they be planted thickly, or near each other, so as to have mutual shelter. A prodigious error is often committed in planting so thinly that the infant trees perish, or at all events grow slowly and very unsatisfactorily. In short, they are killed, or languish for want of mutual protection from cold winds. Stick in the plants almost touching each other. That is a primary principle in planting. As the plants grow in height and breadth, thin them out. Before they are six or eight feet high they may have had to be thinned out two or three times. This looks like a waste of plants, but no other method of treatment will give satisfaction. The plants removed in thinning are susceptible of being transplanted. Still, if transplanted young, it should be in sheltered situations. (For Pruning and Thinning, see further on.)

The different methods pursued in establishing or laying down woodland depend in some measure upon the number of acres and the nature of the ground. Nevertheless, there are certain points which in every case are worthy of the planter's attention; such as the best form for any given extent, the style of boundary, and the mode of inclosure. On these heads we transcribe the advice of a practical forester of long experience: 'As the future welfare of a plantation is considerably affected by the manner in which it is laid out, no man ought to attempt the laying out of ground who is not naturally possessed of good taste for that sort of landscape scenery. It is also necessary that the person who would lay out ground for a new plantation should be possessed of a knowledge of the nature of the growth of each sort of tree when planted upon any given soil or situation.

'The larger that any piece of plantation is, the sooner will the trees come to useful size, and answer the desired end; the smaller it is, the more likely are the hopes of the planter to be disappointed. And the reason of this is obvious: for the young trees growing in an extensive plantation, as soon as they rise a little above the surface of the grass or heath, begin to shelter one another; whereas, if the plantation be narrow, the young trees can hardly be said ever to come the length of sheltering one another—for every breeze of wind blowing through the whole breadth acts upon every single tree almost as powerfully as if each tree stood singly and alone. No young plantation, upon an exposed situation, should be less than one hundred yards broad at any given point.

'The method of laying out plantations in the form of strips, so often to be met with in Scotland, gives a poor and mean appearance to a gentleman's estate, particularly when found about the home grounds. The form in which they have generally been made is in straight lines, from twenty to thirty yards broad. But few such strips are now planted: gentlemen are beginning to see the impropriety of such a method of raising plantations; and now, in almost all cases of good management, we observe the old-fashioned narrow strip giving place to the well-defined, extensive plantation, which is, indeed, the only profitable way of rearing trees for any economical purpose.

'It is absolutely necessary that every piece of ground laid out for a plantation should be fenced in one way or other, previous to its being planted. A fence not only prevents the inroads of sheep and cattle, but it at the same time tends very much to shelter the young trees, and to bring them on rapidly. It is, indeed, surprising to observe the difference that a very low fence makes upon the growth of young trees, as compared with those which are not protected by one. Any proprietor or forester, upon looking through his several plantations, will observe that, in all young plantations, the most rapid-growing, and at the same time the most healthy trees in it, are to be found immediately behind the outer fence; and, upon the other hand, in all older plantations, the best grown, and at the same time the most healthy trees, are to be found in the centre of the same, or at least a considerable distance back from the fence. The reason is that, during the first eight or ten years of the age of any young plantation, the boundary-fence is the only shelter that the young trees have; and it is evident that those trees which grow immediately behind the fence will receive most of the benefit of its shelter; consequently, from the circumstance of their receiving more shelter than their neighbours further off, they grow more rapidly, until such time as their tops begin to rise above the level of the fence, when they are considerably checked by the cold winds. At this stage they begin to grow thick and bushy, rather than advance in height; and immediately upon their becoming so, they begin to shelter all their neighbours inside, which, again, begin to have double the advantage of their neighbours outside; for the trees upon the outside had shelter only so long as they were below the level of the top of the fence, whereas those inside have now a shelter which every year increases upon them for their advantage, in height as well as in thickness. I always calculate that a plantation with a good fence is ten years in advance of one without such protection.'—*Brown's Forester.*

We must now notice the more approved practice applicable to the better kind of soils. In one of the prize-essays published in the *Transactions of the Scottish Arboricultural Society* (vol. I. p. 77), Mr Thomson, of H.M. Chopwell Woods, offers the following valuable observations on this head: 'Planting is a work of the greatest importance, and cannot be satisfactorily executed unless there is due preparation made for it. We often see large tracts of land surcharged with water, and growing only the veriest rubbish, having a few forest-trees studded at irregular intervals over the extent; but such is not planting in the true sense of the word. We apprehend the first thing necessary to attend to in this respect is, to have the grounds carefully laid out into the required form, which, as a matter of course, will have to be regulated by the natural undulations and general outline of the grounds upon which the plantation is to be formed, and the position and aspect which it is desired it should assume. It will, however, be found advisable, in all cases where practicable, to have one side made as much as possible in a convex (or cuneate) form, with the tip of the cone pointing in the direction whence the prevailing winds of the district blow; this is in order that the force of severe gales may

be broken, and not allowed to burst with their full force upon the whole body of the plantation at once. This is a consideration of paramount importance everywhere, but more especially in high-lying and exposed districts. The next step is to have the land properly fenced, in whatever manner may be found cheapest and most efficient; whether by stone-dikes, thorn-hedges, or wire-railing, must depend upon local circumstances and individual judgment and taste. Following immediately upon this, drainage of the land, in all cases where found necessary, should be carried out. Having these preliminary particulars fully completed, and having determined upon what kinds of plants are required, the next step—and a vitally important one it is—is to make a careful selection of the plants that are to be employed. This is a duty no forester who consults his employer's interest, or who has respect for his own character and professional standing, will neglect, seeing that if diseased or otherwise inferior plants are obtained, the whole operation will inevitably end in failure and disappointment, and the expense both of plants and planting will have to be again incurred; and not only so, but the diseases which most commonly infest nursery stock are of a very contagious nature, and will, to a certainty, contaminate the whole adjoining neighbourhood; and when they once obtain a hold in any district of country, it is by no means an easy task to effect an eradication. The greatest judgment and care must therefore be exercised in the selection of forest-trees; it must be seen that both roots and stems are free from bug or other disease, and that they are of a size suitable for the soil, situation, and climate wherein they are to be planted.'

With respect to the choice of trees for different soils and circumstances, the same writer observes: 'With a view to profit only, larch should be more extensively planted than any other kind of tree, as it grows very rapidly, is in constant demand, and generally sells at a remunerative price. Approximate calculations shew that two crops of larch can be brought to maturity in the same space of time required to bring one of oak to perfection; and supposing that both are equally well situated as regards external circumstances, the several sums realised for the former, with accumulated interest, will more than double the amount of income derived from the latter. When it is grown upon good sound land, and found close and firm in the texture, it is in many cases preferred to the best Memel. . . .

'The oak, also, is a tree which will be planted as long as planting continues. Deep loamy soil, or a mixture of clay and loam, upon a rocky formation, is the best adapted for its rapid growth; but from the far-spreading and searching nature of its roots, it will thrive on what is termed "bare rocky ground," if there is sufficient depth of soil wherein its roots may become firmly established; and when once established, it is well known the amount of endurance it will undergo rather than relinquish its hold. On light or gravelly soils, the oak ought not to be planted, as it very soon becomes stunted in its growth upon all such, and never succeeds to large or profitable dimensions. The oak is also valuable on account of the bark it produces, which is employed in tanning. The ash and elm are somewhat similar to the oak in their natural characteristics, and can be successfully grown under much the same general circumstances; only, to grow healthily, the land upon which they are planted should be considerably drier than such as the oak will succeed well in, though it also delights in a dry soil. If dampness pervades the soil upon which these trees are planted, both kinds, but more especially the ash, will soon become covered over with moss and lichen, from the injurious tendency and effect of which it is next to impossible to relieve them. Neither should they be planted upon gravelly soils, as I have observed that in all such cases they invariably decay at an early stage of their growth; and though they may continue to *exist* for a moderate length of time, they do not proportionally increase in bulk and stature, and must, therefore, as a natural sequence, become deteriorated in quality. Where all these kinds of hard-wooded trees—the oak, the ash, and the elm—succeed best, is on a loamy or alluvial soil, with a subsoil of clay, situated upon a substratum of rock or gravel. In marshy places, or along the margin of lakes, water-courses, &c. the birch, the alder, and the poplar may be planted to any extent, as they luxuriate in low-lying grounds, which, being their natural habitat, is of course most congenial to their growth. The birch will also grow well on moderately dry lands.

'For planting on light or gravelly soils, the Scots pine should be principally selected, seeing that it flourishes upon the poorest lands, and in the most exposed situations. The *Pinus Austriaca* has to a certain extent superseded the planting of Scots firs during the last few years, and is *supposed* to constitute a good substitute; but its general applicability to the soil and temperature of Great Britain not having yet been fully tested, and possessing, as we do, but little information of its quality as a timber-tree, it would appear to be unadvisable that it should be introduced to the entire exclusion of our own native pine. The timber of the Scots fir is useful for many purposes, and, when fully matured on land favourable to its growth, far surpasses in quality much of the timber imported from foreign countries; whilst no other tree whatever equals in amount the shelter it affords. Even in the most mountainous and exposed districts, and on the barest lands, it thrives in an extraordinary manner; and considering that it combines, in an eminent degree, extreme hardness with general practical utility as a timber-tree, and seeing that it possesses such powers of contending successfully against difficulties in the form of soil, temperature, and aspect, we would earnestly advise that, instead of allowing it to become obsolete, more and more attention should be bestowed on the culture of the real native sorts, and that it should be more extensively planted than ever. The spruce fir also thrives well on light soils; and where the temperature is mild and humid, it forms an excellent tree for admixture with others of various sorts. It will not, however, endure the same amount of exposure as the Scots pine, and should not, therefore, be planted at any considerable altitude; but in moderately elevated situations, it may, with propriety of taste and judgment, be largely introduced, as the shelter it affords is of the greatest consequence to plants of a more delicate nature, and it likewise possesses such natural beauties as to warrant its being cultivated in all woodland scenery.

The beech and sycamore, if not altogether so hardy, without doubt, stand next in that respect to the Scots pine, and will grow most luxuriantly on even the poorest of soils.

'With reference to the beech, I have seen it attain to large dimensions on pure sand; but the soil best adapted for bringing this tree to the greatest perfection is a marly or gravelly clay on a chalk formation, on which it attains to the most elegant stature and beauty. In the south of England—in some cases exposed to the severity of the south-west gales—it grows in a comparatively short space to the most admirable dimensions; and though its timber, on account of its brittleness, is inferior to that of most other hard-wooded trees, the natural and picturesque gracefulness of a good specimen of the beech is such as to command for it a prominent position in every gentleman's park; and, with a view to ornament, we would be fully disposed to class it amongst the first of our indigenous trees. The sycamore also delights in a light soil, and being of a very hardy nature, will thrive well, and may be profitably grown on exposed situations, either by the sea-shore or on high-lying districts. Its timber is of considerable value when of large size, and is applied to many useful purposes.'

The same authority observes: 'In no case does it appear to me advisable that hard-wooded trees should be planted alone or in excessive numbers; for even if a hard-wood plantation be desired, it is better, in the first instance, to plant the requisite sorts amongst a variety of the fir tribe, so that they may be duly sheltered and protected in their youth. Both kinds should also be planted at the same time. The system I practise is—first, to determine at what distances apart the hard-wood trees ought to be placed—say from nine to twelve feet—and having these carefully put in, I next proceed to have the spaces between these plants filled up to suitable distances with firs which have been selected for the purpose. On low-lying grounds, the distances between the plants, over all, need not be less than from three and a half to four feet, beyond which it is unnecessary to extend them, as the thinnings, at even this rate, will be of some small value when the operation of thinning is first required; but on more exposed and colder situations, the rate of planting may be reduced so low as even two and a half feet from plant to plant. The best nurses are larches, Scots pine, and spruce firs; and they may very advantageously be planted in the ratio of two of the former to one of either of the latter, as such a course will be found to be equally beneficial with any other, and decidedly the most profitable.

'As to the time or season of the year when planting operations may be most satisfactorily executed, I would unhesitatingly record the matured opinion I have derived from extensive observation and practical experience, that all such should be conducted and concluded in the four months of November, December, January, and February. . . . On damp lands, and where late spring-frosts prevail, planting may be postponed till the very latest of the dates I have noticed; but if prosecuted beyond this, the operation cannot reasonably be expected to succeed. If the plants are to be put in by the system of what is technically called *pitting*, the pits may be prepared any time before; and the longer previously they are so prepared, so much the better, as the soil cast out of the pits, being exposed to frosts and the ordinary action of the weather, becomes thoroughly pulverised and purified; and is thus put into a sound and healthy state for the reception of the roots of the young trees.

'With regard to the *method* of planting, I consider it preferable in all cases to prepare pits for hard-wooded trees of all kinds, as they require a considerable space to develop the large fibrous roots with which they are, or ought to be, furnished. The dimensions of these pits must be regulated by the size of the plants they are designed to contain. In ordinary cases, I would say that pits from twelve to fifteen inches in diameter would suffice for every necessary purpose; they should also be made perfectly circular, and fully as wide at the bottom as the top. Pitting will also be requisite for all kinds of firs, where planted on stony or any kind of hard ground; but in loamy, or any other sort of friable soil, I find the ordinary system of notching to be decidedly the best, and by far the cheapest. Where, however, pitting is found to be indispensable, I would advise that the expense of casting the soil actually out of what may be termed the pit, and replacing it again, should not be incurred; as, if it is well stirred all round to the required dimensions with the end of the mattock—the utensil employed in this service—the whole advantage resulting from the system of pitting is equally well secured, the plants are more easily put in, and the cost is comparatively trifling. Trenching may also be found necessary in some isolated cases, but the enormous expense it incurs precludes its general application, even though it were advantageous in every instance, which is not the case. However planted, the utmost care must be exercised, so that none of the roots of any fir may be cut off with the edge of the spade, which is too often done by ignorant or careless labourers; and though not easily detected when committed, this species of injury is doubtless the parent of many of the casualties which occur in the earlier years of some of our plantations. Due regard must also be had to the *sizes* of plants most suitable for different localities, with respect to situation and climate; for moderately sheltered grounds, I would say that oaks about one and a half foot high, one and two years' transplanted larch, two years' transplanted Scots fir and spruce, would be found to be the most suitable; on more exposed situations, two years' seedling larch, with one year transplanted spruce and Scots fir, will answer better than those of a larger size.'

When a large extent of *inferior* land is intended to be planted, it must necessarily be executed in the most economical manner, and without many of the preparations above recommended. If the surface be irregular, and covered with short herbage, two or three year old plants of larch, Scots fir, birch, intermixed with a few oak, beech, and ash, may be inserted at proper intervals by forming notches in the turf. One or two blows of the tool raises a triangular piece of the surface, under which the root of the plant is properly placed, and the raised sod turned back and trodden down with the foot. In this simple and expeditious way of planting, many hundred acres of hilly land have been stocked with trees; and

though many of the plants are liable to suffer, if a dry summer follows the planting, a majority are sure to succeed, which well repays the cost. Notwithstanding the risk of being defeated in such attempts, it is quite certain that in numberless cases they have succeeded admirably; and very valuable woods now ornamenting both England and Scotland have been raised under these simple modes of planting. When such ground is level, an opening is made by first cutting the turf in the shape of a cross, and turning back the four corners from the centre, breaking up and making a hollow for the root: when the tree is placed upright, the turf is returned, and trodden firmly down.

But in planting rough unprepared ground, especially where it is very hard, it will sometimes be found advisable to incur the expense of *pitting*, even where the pits have not been prepared beforehand, as above recommended. The surface-covering is first cleared off, the pit broken up with a mattock, and the loose earth thrown out with a spade; the tree is then placed, and planted with the removed soil.

Before planting, it is always necessary, as we have stated, to see that the land is properly drained, otherwise good timber cannot be produced, and it may be advisable to notice briefly some of the points to be kept in view in draining. The number and extent of the drains will be regulated by the extent of plantation and wetness of soil, which will also indicate the proper distances apart. A depth of between one and a half to three feet is that recommended.

'Before commencing active operations in any portion of land about to be drained for planting, great care must be taken in the selection and provision of a proper outfall. This is of such vital importance, that, were it not attended to, the whole drainage might be rendered totally inefficient, or, in fact, it could not be executed at all. On level land this is more particularly the case, and its perfect execution, both in laying out and cutting, resolves itself into an absolute necessity. Where a large tract of level land has to be drained—a circumstance not likely often to occur—this superfluous absorption causes an increased evaporation from the stem and leaves, the consequence of which is, that a lower natural heat prevails in the plant, and the chemical changes on which its growth depends proceed with less rapidity. The air ought to be able to penetrate into the soil, being, as it is, so essential to the preservation of a proper temperature and to the ramification of roots; and this it can never do in soils where there is an excess of water. To remove, then, this free water, which is the source of so many evils, the cause of so much disease, and the destroyer, consequently, of many sanguine expectations, ought to be the first care of every arboriculturist. Unless this be attended to, no successful result can be attained; the progress of plantations will be tardy; the individual members of them will become deformities, when they would have been ornaments; they will become sickly and die, when they would have been healthy, and yet growing vigorously. . . . The principal object in view in draining wet land is, to cause the whole of the rain-water falling upon the surface of the ground to penetrate readily to a desired depth, and to discharge this water at once, not allowing it to accumulate in the subsoil. This done, the soil becomes pervious, and is then in a fit state for the operation of the planter.'—Rutherford, *Scot. Arbor. Soc. Trans.* vol. I.

When ornamental plantations are made in a park, and especially if they are in view from the principal windows, it is desirable that they should rise as quickly as possible, for the sake of immediate effect; the trees, therefore, receive careful treatment. The ground is not only deeply trenched, but a most liberal dressing of good rotten dung and vegetable mould—the first trenched down, and the latter dug into the surface—is bestowed, which of course excites the trees into much stronger and more rapid growth than if only the ordinary expedients were employed. But this superior and expensive practice is seldom necessary, and much seldomer executed. Indeed, in the rearing of extensive forests for valuable timber, it would be decidedly injurious; for though the young trees might rise rapidly for a few years, as soon as the exciting influence of the manure was over, they would, as all experience teaches, soon fall into a diseased condition, and never attain that hardy robustness which natural forest-timber always presents.

Pruning—Thinning.

When woods are planted as a source of profit, a material part of their subsequent management consists in the labour of pruning and thinning the trees. It is not enough that trees shall grow and be annually increasing in bulk; they should also be assisted to take the finest and most valuable forms, and this in fact greatly affects their increase. A round straight bole, of moderate length, is more useful and saleable than a crooked knotty one of twice the size. To have fine timber, it is absolutely necessary to bestow a little trouble to start them fairly off, during the first ten or fifteen years of their growth. To have tall and straight stems, the trees are planted thickly at first, about four feet apart, or even less; and if in the spring the woodman pays his annual visit, armed with a light keen bill, he may direct the growth with the best effect. Every lateral branch that appears to be attracting too much of the powers of the plant, and especially if, as already observed, it be contending for supremacy with the leader, should be cut off *close* to the bole as soon as it has attained the diameter of an inch. Such a wound will be soon healed up, and present no flaw when the tree is cut up at the saw-pit. If branches are allowed to remain until they have acquired a diameter of from two to four or more inches, and then cut off either close, or, what is much worse, at some distance from the bole, the timber is deteriorated. Such wounds will be healed over in time, but the timber will be wanting in its best property—namely, soundness and freeness from knots.

Trees grown for ornament in lawns require no other pruning than what may be necessary for the removal of rotten or decaying branches; and in general it will be found advisable to leave each kind of tree to assume its own natural form. Ornamental trees are always most beautiful in their proportions when the branches and spray tend towards the ground; but this will not be the case if cattle are allowed to browse beneath and around them. These animals nibble away all the foliage and spray within reach, so as to form an even bottom of foliage, anything but agreeable to

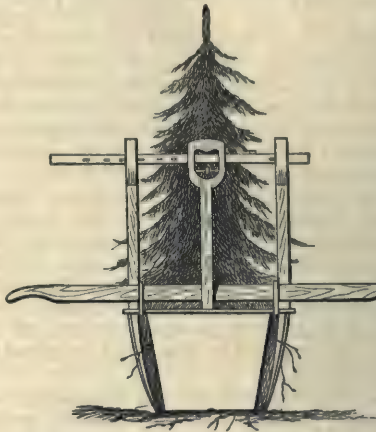
the eye. The only plan of avoiding this inelegance is to exclude browsing animals altogether from ornamental grounds; but this is attended with opposite evils, and takes away that pleasing assemblage of forms which is the great charm of woodland scenery. Where cattle or sheep are permitted to browse, all young trees at least must be protected by circular palings, otherwise they would be barked, and generally destroyed.

Trees increase in thickness fastest when they have about two-thirds of their entire height covered with branches during the whole period that they are increasing in height; these ought to be diminished to between one-half and one-third of the height for a top, according to the sheltered or exposed situation they may be in, care being taken not to draw them up too fast, and then allow them to get top-heavy, as this would bring on too much strain both on root and stem, which in soft soils is very injurious to the tree. Every tree has its own habit; and the pruner must in a great measure adapt himself to the habit of the tree he has to deal with, and not force it into any shape which may please his fancy. We can only assist nature in her operations. One tree, such as the poplar, has a natural tendency to keep to one leading shoot, and to keep its branches within a comparatively narrow space; while the oak has the opposite tendency, if left to nature: its habit is to have a short stem with a wide-spreading top, which may be a beautiful object in certain situations, but certainly not profitable as a timber-tree. Pruning is so closely connected with, and dependent on judicious thinning, that attention to it is of great consequence; for to thin the trees to wide distances will cause them to throw out strong side-branches, and this creates additional work to the pruner; but by keeping the trees pretty thick on the ground, the branches are confined within reasonable limits, and consequently kept from increasing to a large size. It is best, by thinning and pruning, to keep the trees standing quite clear of each other, to allow free circulation of air, and admit the light all round them—both of which are essential agents in the growth of trees; and by this means keep the trees in a healthy growing state, and prevent the branches from becoming large, which always detracts from the value of timber, except where bends and *knees* are formed fit for ship-building. The tools used in pruning are—a strong pocket-knife, hand-saw, a saw with the teeth reversed, a chisel, and the pruning-shears; the last three are fixed on long poles, and they save much loss of time in climbing: for trees further advanced, a ladder fourteen to eighteen feet will be found necessary.

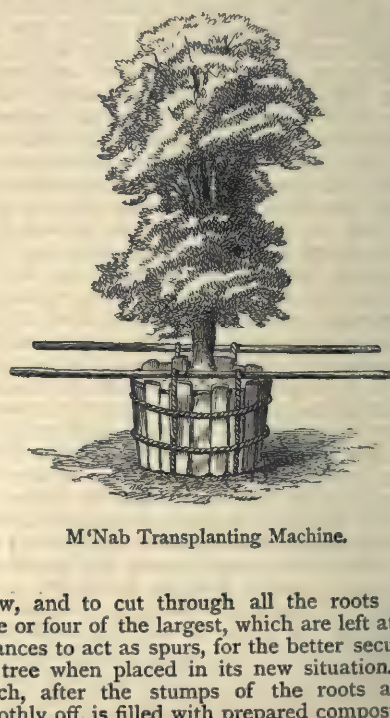
Transplanting.

When single trees are to be planted on a lawn, a space of from four to six feet is stripped of the turf, which is rolled back; the soil within should be deeply broken up and excavated, to receive the full spread of the roots. A heap of rich loam or compost is laid in the centre, on which the tree is placed, and the roots are covered with the same, and watered, to consolidate the earth about the fibres. The other soil is then thrown on, and the turf returned to its place and beaten down firmly. Single trees should be staked; and if on a pasture, a cradle will be requisite to defend them from the browsing or rubbing of cattle.

Much has been written on the subject of transplanting *large* trees, and many successful exploits of this kind have been performed both in past and present times. Shady groves have been formed in the short space of a few months; proving that, with care, skill, and physical force properly directed, any tree of moderate size may be transplanted with safety and success. One precaution very much facilitates the execution: it is that of digging a circular trench at a proper distance, say six feet, round the trunk, and deep enough to be below, and to cut through all the roots except three or four of the largest, which are left at equal distances to act as spurs, for the better security of the tree when placed in its new situation. The trench, after the stumps of the roots are cut smoothly off, is filled with prepared compost, for a



M'Glashen's Transplanting Apparatus.



M'Nab Transplanting Machine.

new fringe of roots to strike into; and after one or two years, the tree is in a condition for removal. In doing this, a deeper trench is made on the outside of the first, into which the mould from among the roots is drawn, until the whole are loosened from the soil; the spur-roots are also followed out and laid bare. The method of raising the tree by a machine is mentioned below. In replanting, much depends on laying out the roots, and firmly imbedding them in moistened earth, and also adding a pretty heavy covering of soil round the stem, to keep the tree steady against wind.

A machine for transplanting has been long in use, on the principle of the common timber-truck—being a strong lever attached to the axle-tree of a pair of wheels.

Many improvements in the apparatus used for transplanting have been introduced of late years, one of the most important of which is that of Mr M'Glashen (patented), by which he is enabled to lift trees of any dimensions. It consists of a number of large spades so arranged as to enter the soil around the tree, and raise it with an attached ball of earth, so that the roots are not

M'Nab Transplanting Machine, for large Trees.

disturbed, those extending beyond the ball being cut through. By a peculiar construction of carriage, the ball of earth can be boxed up, and conveyed to any distance without separating from the roots.

The simplest form of Mr M'Glashen's apparatus is illustrated on the preceding page. Iron spades are driven into the soil at a proper distance from the plant, so as to inclose a square of earth; the upper portions of the spades, after being driven in so as to be on a level with the surface of the ground, are fastened together, either by hooks or an iron frame; and then the handles of the spades are forced out from each other by means of rods, thus causing the lower portion of the spades to press inwards. The whole can then be easily raised by means of levers or screws on either side.

Mr M'Nab, of the Royal Botanic Garden, Edinburgh, has also introduced a system of transplanting. This method is not restricted to transplanting trees, but is also applicable to the re-tubbing of palms and other unwieldy exotics, the same apparatus being available for both purposes. The many improvements that have of late years been introduced in the disposition of the trees and shrubs in the Botanic Garden, have been effected principally by means of this system.

The tree is carefully separated from the surrounding soil, with as many of the roots preserved as possible, and the whole covered with a mat. A piece of cord is then placed loosely round it. Between the cord and the matting are set upright thin boards, from two to three inches apart, all round. A strong rope is then put round the upper and lower parts of the ball, and tightened by means of a rack-pin. The ball is then undermined, and two strong boards pushed under it. Ropes are then passed beneath the boards, and the ends of them brought up and secured to hand-spikes, by means of which the tree is lifted out of the hole, as seen on preceding page; or if the tree is a large one, the ropes are fastened to the rollers of a machine (see above figure), and lifted by turning the cross-wheeled handles. A full description of this powerful machine is given in the *Gardeners' Chronicle* for June 1873.

Coppice—Live-fences.

Coppice or underwood is either natural or planted. Natural underwoods are often the remains of ancient forests which are kept inclosed, and are felled periodically at long or short intervals, according to the purpose for which their produce is to be applied.

Thriving and well-fenced and well-managed coppice is in some cases more profitable than timber-woods. Timber and coppice may be united; the standard trees to stand thinly, and if kept pruned up, the undergrowth is not much hurt by their shade. Mixed underwoods are cut every five, seven, or ten years, unless they are entirely of oak, when they are allowed to stand longer, for the sake of having larger poles, together with the bark, which last is a principal part of their value. The value of the bark has fallen so much of late years, as to render the exclusive growth of this kind of underwood no longer a source of real profit. The reason of the fall in price, which in former years was £16 to £14 per ton, is owing to foreign bark being admitted into the British market free of duty, and sold at prices varying from £5 to £6 per ton, and also owing to the introduction of other substances for tanning, such as divi-divi, myrobalans, valonia, hemlock-bark, &c. No doubt, where old plantations are cut down, it is right and proper that the stocks of them should be converted into coppice-wood,

for this is taking advantage of growths which can be converted into use, and which would otherwise be lost; but to raise up trees to a certain age, and then cut them down prematurely for the sake of their bark, is at best an enormous loss to the proprietor as well as to the country in general.

For *live-fences*, except in peculiarly bleak and barren situations, hawthorn is the best adapted; care, however, is required both in the planting and trimming. The preparation of the land for planting hedges requires the greatest care, for if this be not cleared of weeds before the thorns are planted, it will be almost impossible to do it afterwards. Foul land should be well fallowed before the hedge is planted; and if poor, it will require to be manured. Old pasture-land should be pared and burned, and the ground otherwise well prepared for the reception of the hedge. If possible, the ground should be trenched to about eighteen inches deep, and four feet in breadth, the surface-soil being placed in the bottom of the trench; and this will be found an excellent way of getting rid of weeds. The expense attending a thorough preparation of the soil will be amply repaid by having a clean and well-growing hedge, which is a great ornament to an estate.

The season for planting depends in some measure on the nature of the ground; for if this be very dry, the planting should take place in the autumn, or early in spring, in order that the plants may have made some root before the heat of summer sets in. The autumn is recommended by some as the best season for planting on all soils, and the month of February by others; but perhaps it is immaterial which period be chosen. If spring is the time fixed upon, it should be as early as possible, so that the plants may not have made progress in vegetation before transplanting. There are various modes of planting hedges, some preferring the even ground, others forming a mound, with a ditch at one side, and planting either at the top or on a shelf in the side of the mound; others, again, making a ditch on each side of the mound. If the land be good and dry, the hawthorn will grow quite well upon the level ground; but if the soil be of a wet nature, either one or two ditches will be required. The thorns should be planted at the distance of about three or four inches apart, and about the same depth as they stood in the seed-bed. The plants should then be covered with the finest mould, the points little more than projecting from the front of the mound. A wooden fence may be required to protect the young hedge until it has acquired size.

After being planted, the hedge should be carefully gone over two or three times a year, to cut up weeds. This operation must be performed until the plants have reached some height, and the weeds are completely eradicated, after which the usual cleaning at the roots once a year will be quite sufficient. The plants should never be cut till after three years old, for if cut when younger, the hedge becomes stunted, and is never so healthy. Hedges, when properly established, should be regularly pruned once a year.

When hedges get bare and thin at the bottom, they ought either to be cut over by the root, or to have their sides dressed up close to the principal stems. There is another method of repairing thorn-hedges, which is called *plashing*. It consists in cutting half through the stems adjoining the gap to be repaired, and then bending the upper portion over the vacancy, fastening them down by stakes, or by warping them into each other. By this means a live-hedge is formed more speedily than by planting young shoots, and more effectually than by inserting dead branches. The bent stems soon send out shoots; and if the plashing has been done with care, and that on moderately young and pliant branches, it will be found to be a cheap system, but not permanently efficient.

When thorn-hedges are cut too close by the ground, the decayed stocks should not only be taken out, but the earth where the stocks stood should be replaced with good fresh soil. The thorn-plants intended for filling up blanks should be carefully selected from such as have been transplanted two or three years, have stood thin in the nursery-bed, are well rooted, and free growers.

In high exposed situations, having thin moorish soils, or on hilly land composed of decomposed granite, thorn-hedges are seldom if ever found to thrive. In such situations, the beech has proved itself superior to every other plant, either as an assistant or a substitute for thorns. It retains possession of the soil, and continues to thrive when thorns decay or die out; and when regularly and judiciously cropped, it forms a compact fence, which few animals will attempt to break through. Indeed, experience has proved that, as a hedge-plant, the beech will thrive in any climate or soil; and what is of essential importance, it retains its leaves during winter, giving a genial warmth and shelter, besides being highly ornamental.

A very durable hedge for high situations with a light soil may be formed by an admixture of thorn and beech plants in the proportion of two of the former to one of the latter. Such a fence not only looks well, but lasts well, if trimmed with due care and regularity. Latterly, furze or whins have been employed with advantage as fences. Many other shrubs and trees are used in live-fencing. Among the most common of these are the holly, the privet, and the yew, all of which bear pruning and training almost to any degree.

In maritime situations, where shelter is most wanted, such hedge-plants as the hawthorn and beech do not succeed; but the sea-buckthorn (*Hippophaë rhamnoides*) forms an admirable substitute. When well cared for, it may be trained into a neat and effective hedge, and does not suffer from the sea-breeze, even in the most exposed situations. The plane has also been recommended as a sea-side hedge-plant, but is inferior to buckthorn.

THE HORSE.

THE horse is universally acknowledged to be one of the noblest members of the Animal Kingdom. Possessing the finest symmetry, and unencumbered by those external appendages which characterise many of the larger quadrupeds, his frame is a perfect model of elegance and concentrated energy. Highly sensitive, yet exceedingly tractable, proud, yet persevering, naturally of a roaming disposition, yet readily accommodating himself to domestic conditions, he has been one of the most valuable aids to human civilisation—associating with man in all phases of his progress, from the temporary tent to the permanent city.

In ordinary systems of zoology, the horse is classed with the *Pachyderms*, or thick-skinned animals—as the elephant, tapir, hog, hippopotamus, and rhinoceros. Differing from the rest of the class in many respects, he has been taken as the representative of a distinct family, known by the name of *Equidæ* (*equus*, a horse), which embraces the horse, ass, zebra, quagga, onager, and dzegguetai. All these animals have solid hoofs, are destitute of horns, have moderately sized ears, are less or more furnished with manes, and have their tails either partially or entirely covered with long hair. The family may, with little impropriety, be divided into two sections—the one comprehending the horse with its varieties, and the other the ass, zebra, and remaining members. In the former, the tail is adorned with long flowing hair, the mane is also long and flowing, and the fetlocks are bushy; the latter have the tail only tipped with long hair, the mane erect, and the legs smooth and naked. The colours of the horse have a tendency to *dapple*—that is, to arrange themselves in rounded spots on a common ground; in the ass, zebra, and other genera, the colours are disposed in stripes or bands more or less parallel.

By his physical structure, the horse is fitted for dry open plains that yield a short sweet herbage. Delighting in the river-plain and open glade—the savannas of America, the steppes of Asia, and the plains of Europe, must be regarded as his headquarters in a wild state. There is doubt expressed, however, as to the original locality of the horse. The wild herds of America are looked upon as the descendants of Spanish breeds, imported by the first conquerors of that continent; those of the Ukraine, in Europe, are said to be the progeny of Russian horses abandoned after the siege of Azov in 1696; and even those of Tartary are regarded as coming from a more southern stock. Naturalists, therefore, look to the countries bordering on Egypt as in all likelihood the primitive place of residence of this noble animal; and it is generally believed that the Arabian breed, when perfectly pure, presents the finest specimen of a horse in symmetry, docility, and courage.

In a state of nature, the horse loves to herd with his fellows; and droves of from 400 to 500, or even double that number, are not unfrequently seen, if the range be wide and fertile. It is impossible to conceive a more animated picture than a group of wild-horses at play. Their fine figures are thrown into a thousand attitudes; and as they rear, curvet, dilate the nostril, paw in quivering nervousness to begin the race, or speed away with erect mane and flowing tail, they present forms of life and energy which the painter may strive in vain to imitate. They never attack other animals, however, but always act upon the defensive. Having pastured, they retire either to the confines of the forest, or to some elevated portion of the plain, and recline on the sward, or hang listlessly on their legs for hours together. One or more of their number are always awake, to keep watch while the rest are asleep, and to warn them of approaching danger, which is done by snorting loudly, or neighing. They are seldom to be taken by surprise; but if attacked, the assailant rarely comes off victorious, for the whole troop unite in defence of their comrades, and either tear him to pieces with their teeth, or kick him to death.

There is a remarkable difference in the dispositions of the Asiatic and South American wild-horses. Those of the former continent can never be properly tamed, unless when very young, but frequently break out into violent fits of rage in after-life, exhibiting every mark of natural wildness; while those of America can be brought to perfect obedience, and even rendered somewhat docile, within a few weeks, or even days. It is difficult to account for this difference in temper, unless we suppose that it is caused by climate, or rather by the transmission of domesticated peculiarities, from the original Spanish stock.

SUBJUGATION AND DOMESTICATION.

As in South America we have the most numerous herds, and the most extensive plains for their pasture, so it is there that the catching and subduing of the wild-horse present one of the most daring and exciting engagements. If an additional horse is wanted, a wild one is either hunted down with the assistance of a trained animal and the *lasso*, or a herd are driven into a *corral*—a space inclosed with rough posts—and one selected from the number. The latter mode is spiritedly described by Miers, whose account we transcribe, premising that a lasso is a strong plaited thong, about forty feet in length, rendered supple by grease, and having a noose at the end: 'The corral was quite full of horses, most of which were young ones, about two or three years old. The chief guacho—native inhabitants of the plains are called peons or guachos—mounted on a strong steady animal, rode into the inclosure, and threw his lasso over the neck of a young horse, and dragged him to the gate. For some time, he was very unwilling to leave his comrades; but the moment he was out of the corral, his first idea was to gallop off; however, a timely jerk of the lasso checked him in the most effectual way. The peons now ran after him on foot, and threw a lasso

over his fore-legs, just above the fetlock, and twitching it, they pulled his legs from under him so suddenly, that I really thought the fall he had got had killed him. In an instant, a guacho was seated on his head, and with his long knife cut off the whole of the mane, while another cut the hair from the end of his tail. This, they told me, was a mark that the horse had once been mounted. They then put a piece of hide in his mouth, to serve for a bit, and a strong hide-halter on his head. The guacho who was to mount arranged his spurs, which were unusually long and sharp; and while two men held the horse by the ears, he put on the saddle, which he girthed extremely tight. He then caught hold of the animal's ear, and in an instant vaulted into the saddle, upon which the men who held the halter threw the end to the rider, and from that moment no one seemed to take any further notice of him. The horse instantly began to jump in a manner which made it very difficult for the rider to keep his seat, and quite different from the kick or plunge of our English steed: however, the guacho's spurs soon set him agoing, and off he galloped, doing everything in his power to throw his rider.

'Another horse was immediately brought from the corral, and so quick was the operation, that twelve guachos were mounted in a space which I think hardly exceeded an hour. It was wonderful to see the different manner in which different horses behaved. Some would actually scream while the guachos were girthing the saddle upon their backs; some would instantly lie down and roll upon it; while some would stand without being held, their legs stiff, and in unnatural positions, their necks half bent towards their tails, and looking vicious and obstinate; and I could not help thinking that I would not have mounted one of those for any reward that could be offered me, for they were invariably the most difficult to subdue.

'It was now curious to look around and see the guachos on the horizon in different directions, trying to bring their horses back to the corral, which is the most difficult part of their work; for the poor creatures had been so scared there, that they were unwilling to return to the place. It was amusing to see the antics of the horses; they were jumping and dancing in various ways, while the right arm of the guachos was seen flogging them. At last they brought the horses back, apparently subdued and broken in. The saddles and bridles were taken off, and the animals trotted towards the corral, neighing to one another.'

To hunt down the horse in the open plain requires still greater address, and greater strength of arm. According to Captain Hall, the guacho first mounts a steed which has been accustomed to the sport, and gallops him over the plain in the direction of the wild herd, and circling round, endeavours to get close to such a one as he thinks will answer his purpose. As soon as he has approached sufficiently near, the lasso is thrown round the two hind-legs, and as the guacho rides a little on one side, the jerk pulls the entangled horse's feet laterally, so as to throw him on his side, without endangering his knees or his face. Before the horse can recover the shock, the hunter dismounts, and snatching his *poncho*, or cloak, from his shoulders, wraps it round the prostrate animal's head. He then forces into his mouth one of the powerful bridles of the country, straps a saddle on his back, and bestriding him, removes the poncho, upon which the astonished horse springs on his legs, and endeavours, by a thousand vain efforts, to disencumber himself of his new master, who sits composedly on his back, and by a discipline which never fails, reduces the animal to such complete obedience, that he is soon trained to lend his whole speed and strength to the capture of his companions.

The subduing of wild specimens in America, the Ukraine, Tartary, and other regions, must be regarded as merely supplementary to that domestication which the horse has undergone from the remotest antiquity. A wild adult may be subjugated, but can never be thoroughly trained; even the foal of a wild mother, though taught with the greatest care from the day of its birth, is found to be inferior to domestic progeny in point of steadiness and intelligence. Parents, it would seem, transmit to their offspring mental susceptibility as well as corporeal symmetry; and thus, to form a just estimate of equine qualities, we must look to the domesticated breeds of civilised nations. At what period the horse was first subjected to the purposes of man, we have no authentic record. Trimmed and decorated chargers appear on Egyptian monuments more than four thousand years old; and on sculptures equally, if not more ancient, along the banks of the Euphrates. One of the oldest books of Scripture contains the most powerful description of the war-horse; Joseph gave the Egyptians bread in exchange for horses; and the people of Israel are said to have gone out under Joshua against hosts armed with 'horses and chariots very many.' Thus we find that in the plains of the Euphrates, Nile, and Jordan, the horse was early the associate of man, bearing him with rapidity from place to place, and aiding in the carnage and tumult of battle. He does not appear, however, to have been employed in the useful arts of agriculture and commerce; these supposed drudgeries being imposed on the more patient ox, ass, and camel. Even in refined Greece and Rome, he was merely yoked to the war-chariot, placed under the saddle of the soldier, or trained for the race-course.

As civilisation spread westward over Europe, the demands upon the strength and endurance of the horse were multiplied, and in time he was called upon to lend his shoulder indiscriminately to the carriage and wagon, to the mill, plough, and other implements of husbandry. It is in this servant-of-all-work capacity that we must now regard him; and certainly a more docile, steady, and willing assistant it would be impossible to find. But it is evident that the ponderous shoulder and firm step necessary for the wagon would not be exactly the thing for the mail-coach; nor would the slow and steady draught, so valuable in the plough, be any recommendation to the hunter or roadster. For these varied purposes, men have selected different stocks, which either exist naturally, or have been produced by a long-continued and careful system of breeding. In a state of nature, the horse assumes various qualities in point of symmetry, size, strength, and fleetness, according to the conditions of soil, food, and climate which he enjoys. It is thus that we have the Arabian, Tartar, Ukraine, Shetland, and other stocks, each differing so widely from the others

that the merest novice could not possibly confound them. Besides these primitive stocks, a thousand *breeds*, as they are called, have been produced by domestication, so that at the present time it would require volumes even for their enumeration.

DOMESTICATED VARIETIES.

The following is a brief notice of the leading varieties or breeds now common in Britain:

The Arabian.

The Arabian horse is considered to occupy the highest rank among the numerous cultivated varieties, and embodies that qualification in its purest condition, known by the term *thorough-bred*. The pure Arabians are somewhat smaller than our race-horses, seldom exceeding fourteen hands two inches in height. Their heads are very beautiful, clean, and wide between the jaws; the forehead is broad and square; the face flat; the muzzle short and fine; the eyes prominent and brilliant; the ears small and handsome; the nostrils large and open; the skin of the head thin, through which may be distinctly traced the whole veins of the head. The body may, as a whole, be considered too light, and the breast rather narrow; but behind the arms, the chest generally swells out greatly, leaving ample room for the lungs to play. The shoulder is superior to that of any other breed; the scapulæ, or shoulder-blades, incline backwards, nearly in an angle of 45°; the withers are high and arched; the neck beautifully curved, and the main and tail long, thin, and flowing; the legs are fine, thin, and wiry, with the pasterns placed somewhat oblique, which has led some to suppose that the strength was thereby lessened, which is by no means the case; the bone is of uncommon density, and the prominent muscles of the forearm and thigh prove that the Arabian is fully equal to all that has been said of his physical powers.

The Arabs of the Desert have made the breeding of horses their sole occupation for ages bygone; and from their strict attention to certain rules, they may be justly regarded as the first breeders in the world. They take infinite trouble in grooming their steeds, and are extremely regular in their hours of feeding them morning and evening. They get but little drink, and that is supplied to them two or three times a day; they conceive that much water not only destroys their shape, but also affects their breathing. In spring, they are pastured on dry aromatic herbage; and during the rest of the year they are fed on barley, with a small quantity of straw; and they are the hardiest horses in the world. The Arab trains his horse by kindness, and never on any occasion strikes it; the consequence is, that the animal shews a degree of affection and tractability in which most British horses are quite deficient. The pure Arab horse is employed only for riding, and possesses great fleetness.

The Arabs are exceedingly particular regarding the pedigree of their horses; and they have amongst them a breed which they declare has descended from a horse of King Solomon. It must not, however, be supposed that all the horses of that country are of the finer kinds; for the Arabs have three distinct breeds; the two inferior kinds, they allege, were introduced from India and Greece. The superior kinds they call nobles; and they are never sold without a pedigree, which is most scrupulously attended to.

The British Racer.

The British race-horse is a cultivated breed, originally sprung from the Arabian, and to which is traced the quality of being *thorough-bred*. The skins of race-horses are delicate, with short hair, usually tending to the bright-brown or bay generally characteristic of the horses of the East, and

Race-horse.

sometimes to the gray, prevalent likewise among the Arabs and Barbs. They are frequently chestnut, which may be looked upon as a mixture of the dun or tan colour of some of the races of Northern Europe with the finer brown or bay; and sometimes, though very rarely, they are of the bright-black common to the great horses of the plains of Germany. They are of medium height, rarely exceeding fifteen hands. Their form is that which an almost exclusive attention to the property of speed has tended to produce. They have the broad forehead, the brilliant eyes, the delicate muzzle, the expanded nostrils, and the wide throat, characteristic of their Eastern progenitors. Their light body is comparatively long, and suited to the extended stride. Their chest is deep, so as to give due space to the lungs, but comparatively narrow, preventing the fore extremities from being overloaded, and the limbs from being thrown too far asunder in the gallop. Their shoulder is oblique, to give freedom of motion to the humerus; and their haunch is long and deep, beyond that of any other known race of horses, indicating the length of those bones of the hinder extremities on which the power of progression essentially depends. Their limbs are long and muscular to the knee and hock, and below, tendinous and delicate; and their pasterns being long and oblique, give elasticity to the limbs.

The pedigree of race-horses is always a matter of consequence to the breeder and purchaser of these animals, and is preserved with the same degree of care as the genealogy of many a noble family. By jockeys and others, therefore, a list or stud-book is kept of the sires and dams of their horses, which can be exhibited if required. The pedigree of many fine racers of the present day is traced through stud-books to the Darley Arabian —a horse purchased by a Mr Darley at Aleppo,

from which it was imported to England. One of its immediate descendants was the celebrated *Flying Childers*, bred by Mr Childers of Carr House. This beautiful racer is reputed to have been the fleetest runner ever known in England, or perhaps in the world. On one occasion he ran (carrying nine stones two pounds) round the course at Newmarket—which measures three miles, six furlongs, and ninety-three yards—in six minutes and forty seconds.

Horse-racing is essentially an English sport, with its head-quarters at Newmarket, Epsom, and Doncaster. Of recent years it has been taken up with ardour both in France and America. Many object to it as cruelly taxing the strength of a noble animal; but when the distances to be run are not too great, and where steeple-chasing is prohibited, the race becomes a legitimate test of fleetness, courage, and endurance, and thus tends to perpetuate and improve a superior breed. Unfortunately, the sport is too often mixed up with dissipation, fraud, and gambling.

Hunters, Coach-horses, Hackneys.

The hunter is a combination of the thorough-bred race-horse and half-bred horses of greater strength and bone; but changes are continually taking place in its character. The older race of hunters has been giving place to one of lighter form and higher breeding, and even the thorough-bred horse is now employed by numerous sportsmen. In his improved state, the hunter may rank as a saddle-horse of the first class, combining strength with fleetness. The prime qualities of a hunter may be briefly summed up—head small, neck thin, crest firm and arched, a light mouth, broad chest, body short and compact, the hocks well bent, power behind to push him over difficulties, and broad well-made feet turned outward. The charger or cavalry-horse partakes of the qualities of the hunter.

The better kind of coach-horses owe their origin to the Cleveland bay, and are principally bred in Yorkshire, Durham, and the southern districts of Northumberland; and some few have been produced in Lincolnshire. The coach-horse is produced by a cross of the Cleveland mare with a three-fourth or thorough-bred horse, which is possessed of sufficient substance and height. The full-sized coach-horse is, in fact, only an overgrown hunter, too large for that sport.

The term *Hackney*, in common use, is employed to denote a kind of horse fitted for general services, and is therefore understood to exclude the horses of the highest breeding, as the thorough-bred horse and hunter; and there is further associated with the idea of a hackney, an animal of moderate size, not exceeding fifteen hands, and possessing action, strength, and temper. The trot, rather than cantering or running, is the distinguishing characteristic of a good hackney. Indeed, they should never be permitted to go at any other pace than a trot, which is undoubtedly much better adapted for the road than cantering.

Nothing is more essential in a hackney than sound strong fore-legs, and also well-formed hind ones; his feet must be quite sound, and free from corns, to which hard-ridden horses are very liable; and he ought only to lift his fore-legs moderately high. Some are of opinion that he cannot lift them too high, and conceive, while he is possessed of this quality, he never will come down. There is a medium, however, in this, as a horse that raises his fore-legs too high in trotting is always disagreeable in his action, which greatly shakes and fatigues the rider; besides, he batters his hoofs to pieces in a few years. The principal thing to be attended to is the manner in which the hackney puts his feet to the ground; for if his toes first touch the road, he is sure to be a stumbler. The foot should come flat down on the whole sole at once, otherwise the horse is not to be depended upon in his trotting.

The proper kind of saddle-horse is only a variety of the hunter, possessing less or more breeding, according to the nature of the work required of him, and the taste of the breeder. Of the great varieties of saddle-horses, there may be said to be a chain of connection, as respects spirit and form, from the racer to the cart-horse; and therefore the station which any individual occupies is almost undefinable. The saddle-horses of England are celebrated for their beauty and action; and nowhere are seen so many of elegant forms as in London. Latterly, the breeds have been tending to greater lightness, the state of the roads not now requiring the weight and substance which was at one time necessary.

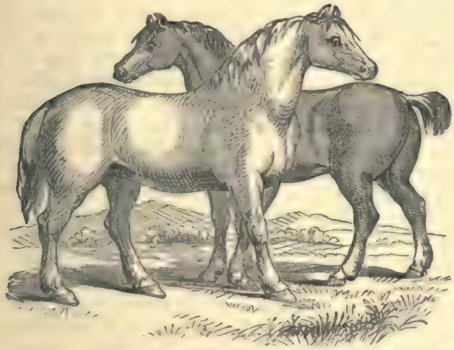
The Cart or Draught Horse.

The cart-horses of Great Britain are extremely variable in point of size as well as in shape, differing in almost every county. One principal character, however, is weight, to give more physical force in the draught. They should not be above sixteen hands high, with a light well-shaped head and neck, short pointed ears, with brisk sparkling eyes; their chests should be full and deep, with large and strong shoulders, well-raised withers, and deep wide chest. The back should be straight, and rather short, the ribs well arched, and the space between the last rib and the haunch-bone short. A long-carcassed, flat-ribbed horse tires easily, eats voraciously, and thrives badly. The limbs, strong, flat, and muscular, and well placed under the body, should not be disfigured by too much hair—a very common fault in the heavier English horses. The joints should be large and pliant, the feet wide, tough, and sound; and with limbs and feet such as these, the cart-horse will be able to walk easily four miles an hour, or plough his acre daily. For ordinary farm-work, we prefer strong-boned, clean-limbed horses with some breeding, and with the activity and courage which accompany breeding, to the coarser, heavier, more sluggish race still too prevalent.

In the midland counties of England—Warwickshire, Derbyshire, Leicestershire, Lincolnshire, and Nottinghamshire—there is a very large breed, called the great cart-horse. It was bred in the lowland rich alluvial pastures of the plains of these counties, from the Flemish and Dutch horses with the larger English breed. Mr Bakewell introduced horses, and also mares, from the Netherlands, and thus produced those fine animals with Belgic blood both on the side of the sire and dam. The very large horses of seventeen hands and upwards are only useful for the purposes of brewers' drays, wagons, and the slop-carts of London. It is, however, doubted if they answer the better for their gigantic size; and all who have

written on the subject, consider that they are inferior in point of strength, on account of their bulk; for by the feeding which is required to increase their dimensions, little of muscular fibre is produced, the growth being principally in the cellular tissue and fat; and the additional quantity of food required to keep up their system, must more than counterbalance any advantage to be reaped from their size.

Latterly, considerable pains have been taken to improve the qualities of ordinary cart-horses, among which we include those required in agriculture. A breed called the Clydesdale is highly valued for either cart or plough. Animals of the Clydesdale breed reach to a large size, and are not unfrequently to be met with sixteen and a half hands high. These animals are strong and hardy,



Clydesdale Horse—Suffolk Punch.

but their heads are somewhat coarse, and they are rather flat on the hinder quarters. The usual colour of these horses is gray or brown. This breed is supposed to have originated about one hundred and forty years ago, between the common Scotch mare and the Flanders horse. As a breed, the Clydesdale is rapidly rising in estimation, and is now extensively used.

Ponies.

A horse beneath thirteen hands is called a pony, but this definition is not very strictly attended to, and the same thing may be said of the *galloway*. The old Scottish galloways, which took their name from the district of Galloway, in the south-western extremity of the country, are now nearly extinct. They were stout, compact animals, sure-footed, and of great endurance, and on these accounts invaluable in travelling over rugged and mountainous districts. The beauty and speed of the galloway were supposed to be owing to its being the result of a cross between Scotch horses and some Spanish jennets, which escaped from the wreck of the Spanish Armada. But we believe the breed was famous long before that event, as this district is known to have supplied Edward I. with great numbers of horses. They seldom exceeded fourteen hands in height: their colour was generally bright bay or brown, with black legs, small head and neck, and their legs peculiarly deep and clean. A compact, stout-built pony, of from thirteen to fourteen hands high, and possessing some of the qualifications of the galloway, is called a *cob*, which is valuable as a steady pacer, at an easy rate.

The small ponies of the Highlands of Scotland and Shetland (usually called *shelties*) may almost be termed wild animals; for they go at large in herds on the hills and wastes, and are not shod till caught and put into training. They are docile and tractable, and being very sure-footed, are the best adapted for boys' riding. The Welsh pony is more handsomely formed than that of Shetland; has a small head, high withers, deep round body, and excellent feet. The Exmoor and Dartmoor ponies are also a hardy, sure-footed race, well adapted for riding in wild districts. The ponies of Norway and Sweden, which are of a dingy cream colour, and of which there are now occasional importations to Britain, are considerably larger than the Shetland or Welsh breeds, and are hardy, sure-footed, and docile.

REARING OF HORSES.

The breeding and rearing of horses are carried on professionally in England, chiefly in Yorkshire; but many private gentlemen and farmers also engage in it as a means of pecuniary profit and the improvement of their animal stock. We do not pretend here to offer any specific directions on this branch of our subject, it being one in which the public at large are not particularly interested; and a few observations seem all that is necessary.

The circumstance which the breeder of horses requires to keep most in mind is, that the qualities, good or bad, of the animal are hereditary. Finely made horses produce finely made descendants, and *vice versâ:* heavy cart-horses never produce animals possessing the qualities of racers. Thus the bone, blood, and general make are directly transmissible; and, in the case of crossing, the produce is found to possess a proportional share of both sire and dam. Cross-breeding between extremely different horses is not found advantageous: it is a generally recognised principle, that the nearer the resemblance between the parents, the more satisfactory will be the produce. Mr Smith, in his *Observations on Breeding for the Turf*, remarks, that 'the stock of some mares will frequently partake most of the dam, and that of others, most of the sire; and sometimes one foal will partake most of the mare, and the next perhaps, most of the horse, &c. It also occasionally happens that the produce bears some resemblance to its grandsire, grandam, or other distant kindred; and although this does not perhaps often occur, so as to be very perceptible, yet as their qualities must, in a lesser or greater degree, descend to their progeny, it has always had its due weight; hence the value and partiality to blood, or ancestral excellences, transmitted through many generations.' He further observes, however, 'that he is disposed to attribute more in general to the dam than to the sire, inasmuch as he is decidedly of opinion that a good mare put to the worst thorough-bred horse would be much more likely to produce a runner, than a bad mare put to the most fashionable stallion in England; and therefore a person possessing good mares may bring any stallion into repute.' The grand aim of the breeder must be the propagating of excellences, and avoiding defects; but this is not to be accomplished, as

respects important alterations, all at once; improvements in this, as in everything else, being the work of time and a judicious experience. Breeding *in-and-in*, as it is called, or between close relationships, is decidedly pernicious, and should by all means be avoided.

The season for mares is about February and March, but in some cases it continues later; and the term of gestation is generally over eleven months. The foal remains with the mother till weaned, which takes place earlier or later, according to the quantity of milk, the strength of the animals, and the season of the year. On removal, it requires to be carefully attended to, and provided with soft nourishing diet. Few things contribute more to the health and perfection of young horses than a sweet, sound, and hard-bottomed pasture-range.

The operation of cutting is seldom performed on thorough-bred colts, but with all others it is common. It is an operation which ought by all means to be left to the veterinary surgeon or skilful farrier. The best authorities recommend it to take place with young cart-horses when four or five months old; but if for carriage or light work, it may very properly be postponed till the animal is twelve months old. The use of the operation is to render the horse more submissive than if left in an entire state, and to devote him altogether to the work he is required to perform. The advantages, whatever they are, are in some measure lessened by the lowering of spirit. The practice, however, is universally recognised in Britain, as one indispensable where numbers of horses are congregated, and required to be kept in good condition.

Breaking, or reducing the young animal to obedience, is a most important point in the education of the horse. If previously accustomed to handling, the difficulty of breaking will be much lessened. Racing-colts are now begun to be broken at one year old, and saddle-colts at two years, and are finally and fully broken and trained, some at three, and few later than four years old. Breaking horses is a regular business, and is best left to the person who is well accustomed to it, provided he follow a judicious course of treatment. As in the training of children, gentleness, with firmness, ought to be a prevailing principle of management. The chief apparatus of breaking is a powerful bridle or head-tackle, with boots or pads strapped on the legs, to prevent them knocking against each other. The young horse is to a certain extent trained before his back is mounted; all the preliminary part of the process of subduing being accomplished while he is led by the bitted tackle. His back is not to be mounted till he is evidently able to endure the load without injury to his figure: too early mounting is apt to make him hollow-backed for life. In putting on a saddle for the first time, great caution should be taken; let the girths be drawn loosely, the crupper smooth, and keep the stirrups from dangling. In short, the animal requires on this trying occasion to be treated with as much kindness as it is possible to employ.

Having, by the various means which are adopted, brought the animal into subjection, and in effect taught him that he must in future act the part of a dutiful servant to an indulgent but firm master, the next step is to teach him his paces. These are partly artificial. Commence with slow and regular walking; whenever he is inclined to bolt, bringing him back to the steady pace you desire. After he has been accustomed to slow paces on a methodic plan, go on to the slow trot, then the quick trot, and, lastly the canter and gallop. By no means allow him to mix these paces—that is, half-canter and half-trot—which would be an ungainly hobble; but let him know that he must, for the time being, keep to one kind of pace. The skill of the breaker consists in enforcing these lessons, and teaching the animal to change readily and neatly from one pace to another by little more intimation than a twitch of the rein. The first shoeing ought to be performed with great care, so as to alarm the animal as little as possible.

In connection with the breeding of horses, we may say a few words respecting *mules*, or the hybrid offspring of the horse and ass. The mule proper is the produce of a male ass and mare; when the parents are the horse and she-ass, the produce is called a *hinny*. The mule is the superior animal, partaking to a larger degree in the qualities of the horse; it is more robust, plump, and hardy, and better adapted for all the ordinary purposes of riding and draught. The hinny is more thinly made, has a longer head, and is altogether more like the ass than the horse. Mules of both kinds live to a very old age, and when properly trained, they are tractable, and very serviceable animals. There are comparatively few mules in Britain; but in Spain, and some other countries of Southern Europe, also in Spanish America, they are numerous, and are used in carriages of people of the highest rank. According to a well-known principle in natural economy, by which intermixture of kindred species is not allowed to go beyond a single step, and only for one generation, mules do not usually breed; and the stock requires to be kept up by a recurrence to the common parentage.

The Teeth—Age.

The horse attains maturity at five years old, and he is in his prime till eight or nine. If no unfair play be used, his age may be judged of from his teeth, or, as it is called, *mark of mouth*. At five years old, when the teeth have been fully developed, the horse possesses six teeth in the front of each jaw, called the incisors or *nippers;* it is with these teeth that he bites. At a short distance from each end of the row of incisors, and in each jaw, there is a solitary canine tooth; these canine teeth are technically named *tushes*. At a greater distance inward in each jaw, and on each side, there are six grinders—the whole apparatus being designed to bite or crop the herbage, to tear, and to chew. At five and a half years old, the nippers are marked by a natural cavity formed in the substance between the outer and inner walls, and it is the presence or absence of these darkish marks that certifies the age of the animal. When the horse reaches six years, the marks in the two front nippers in the nether jaw are filled up, and the tushes are blunted. At seven years, the two nippers next the middle ones are also filled up; at eight, the two outer ones are filled up also, and the tushes are round and shortened. The lower nipper teeth are now all smooth; the marks are gone; but in the teeth of the upper jaw, marks remain a year or two longer. At eight years, the disgraceful practice of *bishoping*—a term given

from the name of the inventor—is often resorted to, for the purpose of imitating the obliterated marks. An engraving tool is employed to cut the surface, and a hot iron is then applied to give a permanent dark stain. This infamous trick may impose on the ignorant; but a person skilled in horses can easily detect the imposition, from the stains being diffused around the marks, which, moreover, are round instead of oval.

As a horse, if well treated, remains in excellent working condition till twelve years, and even later, the disappearance of the marks on the teeth is often of little consequence. Some horses are as valuable to their owners at fifteen years as they are at eight; and for ordinary saddle-work, ten to twelve may be considered an age sufficiently young. It is important, however, that the teeth are capable of mastication; for if the animal is unable to chew his food properly, he cannot be kept in good condition, or fit for the performance of his duties. In consequence of the very general abuse of horses, few live till twenty-five years old; and the instances of any living till above thirty are rare.

Technical Terms.

Horsemen employ terms to horses which are not strictly adhered to in ordinary language. A male horse left uncut is said to be an *entire horse*, to distinguish it from the *gelding* or cut animal. A female horse is always spoken of as a *mare*. A young male horse is called a *colt*, and a young female, a *filly*. *Thorough-bred*, as already noticed, is applied only to animals whose pedigree can be traced to an Arabian origin, without stain or any common intermixture. When the pedigree of the racer is to a certain degree stained, the animal is called a *cock-tail*. The term *blood* is of more loose signification; but what is generally understood by it is a horse which is thorough-bred, or of the blood of the Arabian, and consequently shews a fine spirit and action. A horse may be half-bred, three parts bred, and so on, according to his pedigree. The half-bred is produced from a racer and a common mare. Some of the best riding-horses are of this stamp. The term *welter horse* is applied to racers which are able to carry the highest weight.

Horses are measured by *hands*, four inches being reckoned to the hand; the measure is taken from the highest point of the withers to the ground. To all the more prominent parts of the body and members, certain technical names are applied; for example, to take the fore extremities first: the *muzzle* includes the lips, mouth, and nostrils; the *withers* are the sharp protuberance over the shoulders between the back and neck; the breast is the *counter;* the *arm* is the upper part of the fore-leg, but enveloped in the muscle of the shoulder; beneath it is the *forearm*, which is the higher part of the visible leg, and extends downward to the *knee;* below the knee we have another stretch called the *shank*, which extends to the *pastern*, or, as we might call it, the ankle; the *fetlock* is behind the pastern; beneath are the feet. A few of the hinder extremities are named as follows: the *croup*, which extends from the loins to the root of the tail or rump; the *flank*, extending from the ribs to the haunches; and the *leg* or thigh, which reaches down to the *hock* or middle joint of the hind-leg, corresponding to the knee in the fore-leg. The left side of a horse is called his *near* side; and his right, the *off* side.

The greater number of British horses are of a dark colour, inclining to black or brown, but of innumerable shades. One kind of brown is called bay, and another the chestnut; a yellowish chestnut is termed the sorrel. The roan is a blending of red and whitish tones. The gray is a mixture of white and black hairs, and in old age becomes altogether white. The dark colours are the most esteemed for their physical qualities, and patches of white on the legs are considered defects or foul markings.

STABLE MANAGEMENT.

The horse, as has been already mentioned, possesses very delicate senses, and is nice in his habits, in which respect he differs very materially from black-cattle. When reduced to domestication, care should be taken to violate as little as possible his natural tastes and habits. The leading features of management may be defined as follows:

The Stable.

A high authority states it as his belief that nine-tenths of the diseases which afflict horses owe their origin to, or are greatly aggravated by, the defective arrangement and construction of stables. The chief points to be attended to are: the situation of the stable; its construction, so as to prevent damp and secure ventilation; its size; and its fittings and appendages. A stable should never be built in a marshy or hollow spot, but on a gentle declivity, so as to admit of good drainage, and with a southern exposure, in order to command good light—another important point. The first thing in the actual construction is how to secure dryness. The effects of damp on horses are immediately visible in languor, refusal of food, liability to colds and inflammation. Glanders and farcy, if not entirely owing to a humid atmosphere, as some hold, are certainly encouraged and fostered by it. The site of the stable, then, must be surrounded and intersected by smaller drains leading into a main-drain, with a good outfall. The walls again, whether of stones or brick, should be made *double*—the hollow space, in order to prevent the lodgment of rats, being not more than two inches wide. To provide against surface-water rising up the walls by capillary attraction, the first course above the ground may be covered with a coating of coal-tar and sand, or with sheet-lead. The roof should have a range of guttering completely round it, and the rain-water should be collected in a tank for use.

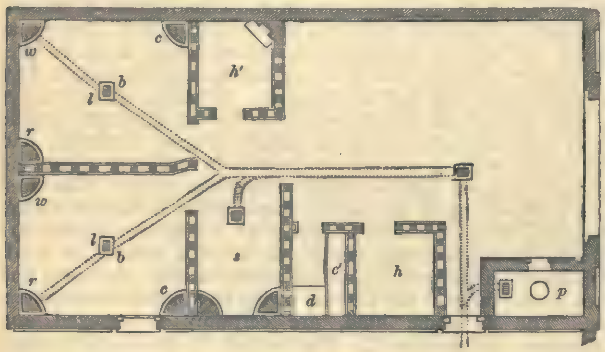
Damp *floors* are so far provided against by thorough under-drainage; but a floor completely impervious to moisture from below may be had by constructing it of asphalt, or of flags set in cement, and with grooved surfaces. Good floors are also made of bricks set on edge, or of tiles with corrugated surfaces. To prevent the lodgment of the urine of the animals, the floors of the stalls should slope two or three inches in ten feet towards a channel running along behind the horses, which channel should itself have a slope towards the grating or gratings of the drain connected with the liquid-manure tank. These drains should be carefully trapped. The slope of the stalls has no injurious or incommoding effects on the horse while reclining, as some have imagined. A dry stable-floor is

effectually secured by the use of Forbes's drain-pavement, in which the flooring-bricks are grooved so as to form a system of channels for the urine.

The inside of the stalls should be boarded, and a lining of wood, four or five feet in depth, should be carried round the bottom of the other walls; all above should be plastered and white-washed.

The evils of defective ventilation to animal life in general (see PRESERVATION OF HEALTH, also WARMING—VENTILATION—LIGHTING) are aggravated in the case of horses by the quantity of ammonia developed from the urine. This is less the case in stables where the floors are kept dry and sweet by the means above described; still, in every stable, means must be provided for the constant removal of tainted air, and the supply of fresh. The principles laid down in the number just referred to will be found applicable here.

A stable should never be large, as it is then liable to great fluctuations of temperature, according to the varying numbers in it at one time. A good size is one with ample room for six or eight horses. A stable with a row of stalls on one side only is better than one with double rows; if double, the space between should not be less than eight or ten feet. Sixteen feet is a proper width for a stable



Ground-plan.

with a single row, ten feet being allowed for the depth of the stalls. Each stall is usually five and a half feet wide, but when space will permit, a width of six feet is advisable.

We give a ground-plan and elevation of what is considered by good judges a model stable, erected by Mr Murray Anderson at Tollington Park, near London. It is planned to accommodate three

Elevation.

horses, and contains coach-house and stable-yard under the same roof: *lb*, *lb* are two loose boxes, having each a rack for hay, *r*, a corn-box, *c*, and a water-trough, *w*; *s* is a stall five feet six by nine feet; *c'* is a corn-bin, and *d*, one for beans; *h* is a hay-shed; *h'*, the harness-room; *f*, the covered yard for cleaning carriages, &c.; *p*, the dung-pit, which is an air-tight tank, with a ventilating tube rising above the roof. The dung is thrown down by a trap-door inside, and removed by another outside. The building is lighted from the roof, which also contains three ventilators for the escape of the air. Fresh air is admitted by gratings at the bottom of the pillars represented in elevation; these being hollow, the air ascends, and enters the stable by similar gratings at the top inside. The whole structure, walls and floor, rests on concrete.

We have now to consider the fittings; and first as to *windows*. When we say that the stable should be well lighted, we certainly oppose one of the most vulgar prejudices respecting horse-management. In most instances, stables are kept as dark as dungeons, greatly to the injury and discomfort of the inmates. It is impossible to understand what can be rationally designed by keeping horses standing in the dark during their waking-hours. Nature never intended anything of the kind, and the practice should be abolished. The best way of lighting is from the roof, the windows being capable of being easily opened from below by means of cords and pulleys; which arrangement furnishes at the same time a means of ventilation. When lighted from the side-walls, Mr Stephens recommends the lower part of the window to be *dead*, the upper part only glazed, and capable of being opened. The stable should be entered by one door only, placed at the end of the building; it should be eight and a half feet high, and not less than five wide. It is advisable to have a spring by which it can be kept open until the horse is clear; when this is released, the door should be so hung as to close itself.

Hay-loft—Racks—Mangers.

The hay-loft, or place of deposit for hay, ought not, as is usually the case, to be over the stable, but adjacent; and a chamber level with the floor of the stable, and behind the stalls, is preferable, the hay being passed into the racks through doors opening from this chamber. In cases where hay-lofts are used, let them be kept as clean as possible, and allow no opening to the racks.

Hay-racks of the best material and form are made of iron, the bars rounded, and two inches from each other. The rack need not traverse the whole breadth of the stall, because in such a plan rubbish collects in the corners. A size to hold from a half to a whole stone of hay will be sufficient in most instances. A convenient form is that of a convex or bulged grating from the wall, placed a little above the head of the horse. A rack of this or any other shape cannot be kept too clean; the bars should be daily rubbed, and all refuse of hay removed. In improved racks, a drawer is provided, into which the *seeds* drop. A very ingenious and economical form has recently been introduced. It consists of a square iron casing, placed in the corner of the stall, the upper

end being formed by a wide grating; a movable bottom slides up and down in the casing, being drawn up towards the top by a weight, which is sufficiently heavy to lift also the hay which is placed upon it. As the horse draws the hay through the top grating, the weight keeps it constantly pressed against it, so that he withdraws only a mouthful at a time, and is prevented from littering it about his stall. Mangers, for the supply of corn, &c. are now almost universally made of iron, with enamelled interiors; they are thus easily kept clean. They should be supplied through a spout regulated from the outside of the stall. Water is also provided now by an iron enamelled trough, to which it is supplied by a special water-pipe and tap, and withdrawn by means of a plug in the bottom leading to a waste-pipe.

Bedding—Cleaning.

The good horse sleeps in a lying posture, his legs being partly drawn under him, and his head remaining up. A horse that habitually sleeps standing, or will not lie down at night, is usually reckoned to be of little value; for it is indispensable to doing his duty during the day that he rests well at night. The preparation of a bed for the animal ought to be one of the most pleasing parts of a stable-keeper's duty, and he should perform it well. The best bed is made of wheat-straw; but when that is dear, or cannot be got, the straw of oats may suit the purpose. The more even and less rumpled the litter, the better. The bed should be made level, or sloping slightly from the sides and head towards the centre, and be completely free of hard lumps. All ought to be smooth, clean, soft, and the depth of litter perhaps seven or eight inches. Every morning, the soiled litter is to be taken away to the dung-yard, and the clean portion separated and placed at the head of the stall, or in some other convenient situation, ready to be employed again at night. The stable should be clean swept, brushed, and thoroughly ventilated every morning, leaving impurities neither on the ground nor in the atmosphere.

Stable Furniture—Stablemen.

Every stable is to be provided with proper receptacles for hay and straw. The oats, peas, beans, bran, &c. should be kept in one large chest with divisions, or separate chests, and, if possible, be placed in an apartment separate from the stable. For small stables, an adjoining room should be fitted up neatly for the accommodation of the corn-chest, the saddles, and other apparatus; all saddles, bridles, and small articles being properly hung on hooks on the wall, or placed on other appropriate supports. A cupboard for combs, brushes, &c. will be an advantage. If the stable be not supplied with water in pipes, a well should be at hand.

Horses require to be under the charge of persons who understand the business of attending to them in all their varied wants. Some individuals seem to imagine that any boy or lad will do for taking care of a horse. This is both inhumane and bad policy. Where only one horse is kept, a steady lad, under the directions of his master, and instructed in the line of his duty, will often be found sufficient; but he requires constant looking after.

In stables in which two or more horses are kept a regular groom should be employed; and he should reside close by the stable, so as to be always at hand. The qualifications of a groom ought to be steadiness of conduct, promptitude in a case of difficulty, openness to advice or instructions, experience in well-managed stables, taste for cleanliness; and he should be as desirous of making his charge comfortable as he would his own person.

If all horses were good-tempered, or rendered docile by kind treatment, they might be advantageously left at liberty in their stalls; circumstances, however, require that they should be restrained; but this should be done with as little pain to them as possible. The halter or rein from the headgear should be led to a ring at the head of the stall, leaving the animal at liberty to lie down in an easy posture. The rein, whether of rope or chain, should not be tied to the ring. It should go through the ring, and drop down with a plummet at the extremity to keep it down, yet allowing the animal to pull it up or allow it to sink at pleasure. A shorter halter may be employed during the day than at night, so as to keep him from straggling backwards into the passage or gangway.

Grooming—Dressing—Trimming.

The skins of horses are liable to become clogged with a scurf of dried perspiration, along with particles of dust and mud, which collect and lodge among the hairs. It is of great importance to remove these impurities by currying and brushing, for the sake of the health of the animal, independently of the value of the operation as respects the appearance of his coat. The degree to which this species of grooming is carried will of course very much depend on circumstances; but, as a general rule, it should take place every morning before the horse is led forth to the labour of the day.

If horses are not groomed regularly they will inevitably lose their health, or be troubled with parasitical animals lodging beneath the hairs, and never have a glossy and cheerful appearance. Some horses have a great repugnance to being groomed, but this generally arises from harsh treatment while they were young: if treated considerately, they will feel pleased with the friction, and grateful for the attention bestowed on them.

The cleaning of a horse after work is as necessary as the morning grooming. When a horse is brought to the stable in a state of perspiration, it should not be taken in to be at rest all at once, but be walked gently about till it becomes moderately cool. This allows the excitement of the blood-vessels and muscles to be allayed gradually, and prevents any sudden stoppage of the pores of the skin. To assist in drying and cooling down the animal, he may be scraped or rubbed with wisps. Wisping is preferable. After the horse has been walked and wisped, his legs and feet should be washed with water and a brush or sponge, and also his belly, if it be dirty with sparks of mud; but, after any such washing, every part should be thoroughly dried with a fresh wisp. Never leave a horse with wet legs or feet. In the country it is not unusual to walk horses into a river to wash their legs—a practice most detrimental to their health, and which should not be allowed.

When the horse has been cleaned and dried,

the cloth may be thrown over him, and he may be tied to his stall. The cloth used in summer should be lighter than that used in winter. It is customary for grooms to exercise horses with the stable-cloths wrapped round them, and then perhaps the next hour they are taken out saddled, and without any cloth at all. This seems an inconsistency. The use of cloths is to protect the animal's loins from cold, and is unnecessary in fine weather. If the horse has to stand still out of doors, and the weather be ungenial, his loins ought by all means to be protected by an oiled cloth. The horse is very susceptible of injury by exposure of the loins; and it will be observed that, to shelter that part, cavalry soldiers wear a long riding-cloak, which falls loosely over the hinder part of the animal.

Nature gives the horse a beautiful flowing tail and mane, for the purpose of whisking off flies, and for other uses; but mankind, in taking the creature under their protection, have in many instances, and for no good reason, as far as we are aware, deprived it of these graceful personal appendages. The most contemptible piece of this rash interference has been the docking of the tail, and causing it to cock up, thus leaving the rear of the animal exposed. The tail should be left flowing to a point, and only trimmed to a limited extent; and the same thing may be said of the mane. Nature has likewise given the animal long hairs on the legs independently of the fetlocks. These various appendages have likewise not been given unnecessarily; they answer as a kind of thatch to carry off the moisture which trickles down the legs, so as to keep the feet dry and the legs warm. These parts, therefore, should be trimmed sparingly; and the fouler the animal's work, the more should be left on. Any trimming should be executed tastefully with a comb and pair of scissors. It is customary to clip away the long hairs about the ears and muzzle, but this also must be performed with great discretion. These hairs have their uses, those about the ears in particular, and harm is not unfrequently done by their removal.

Management of the Feet.

When the horse has been stabled for the night, it will be the duty of the groom to see that the hoofs, above and below, have been cleaned, particles of sand removed from the crevices of the shoes, and the feet generally in a good condition. The feet have a tendency to harden and crack, and thus a good horse may become lame. The fore-feet are most liable to this serious evil. To prevent hardness and soreness of feet, it is customary to *stop* them at night with a soft moist material—most commonly cow-dung, mixed with oil, lard, or tar. No special directions on this point can be given; for some thin-soled horses do not require stopping, and the hind-feet are seldom in need of anything of the kind. When the frog is liable to thrush, the feet require to be kept dry, and cleaned and attended to with peculiar care. To prevent over-dryness of hoofs, as well as the undue action of moisture, it is advisable to anoint the horny part of the feet with an ointment made of tar, fish-oil, and bees-wax, melted together in equal proportions; but this should not be done unless it is absolutely required. If well washed, and kept clean, the feet will seldom require any of this kind of varnishing.

When at large in a wild state, horses, as may be supposed, go barefooted, like all the other lower animals. The hoofs grow with a slight curve up in front; but this does not seem to impair their speed. If domesticated horses were always to walk on turf, and were not obliged to carry or draw a weight, their feet might remain unshod; but the circumstances of their condition make it necessary to protect the hoofs from tear and wear by means of shoes. Horse-shoes have been used of many different shapes and materials; but it is needless here to speak of any others than the iron shoes in common use. The shoe must be of weight conformable to the powers and uses of the animal, made exactly to suit the curve of the hoof, flat, and of equal thickness, and secured by nails to the hoof. The proper paring of the hoof before shoeing, and the shoeing itself, are matters to be left to the discretion of regular farriers. As a general principle, care must be taken not to drive the nails into any tender part, and the hoof should be as little broken as possible. A gentleman's horse should be shod at regular intervals of three or four weeks, and a shoe never suffered to come off from too long usage.

Exercise.

Every horse, when not worked, ought to be exercised daily in the open air. The exercise should be in the early part of the day. An authority already quoted (*Lib. Use. Know.*) observes: 'The horse that, with the usual stable-feeding, stands idle for three or four days, as is the case in many establishments, must suffer. He is disposed to fever, or to grease, or, most of all, to diseases of the foot; and if, after these three or four days of inactivity, he is ridden fast and far, is almost sure to have inflammation of the lungs or of the feet. A gentleman's or tradesman's horse suffers a great deal more from idleness than he does from work. A stable-fed horse should have two hours' exercise every day, if he is to be kept free from disease. Nothing of extraordinary, or even of ordinary labour can be effected on the road or in the field without sufficient and regular exercise. It is this alone which can give energy to the system, or develop the powers of any animal. In training the hunter and the race-horse, regular exercise is the most important of all considerations, however it may be forgotten in the usual management of the stable. The exercised horse will discharge his task, and sometimes a severe one, with ease and pleasure, while the idle and neglected one will be fatigued ere half his labour be accomplished; and if he be pushed a little too far, dangerous inflammation will ensue. How often, nevertheless, does it happen that the horse which has stood inactive in the stable three or four days, is ridden or driven thirty or forty miles in the course of a single day? This rest is often purposely given, to prepare for extra exertion—to lay in a stock of strength for the performance of the task required of him; and then the owner is surprised and dissatisfied if the animal is fairly knocked up, or, possibly, becomes seriously ill. Regular and gradually increasing exercise would have made the same horse appear a treasure to his owner. Exercise should be somewhat proportioned to the age of the horse. A young horse requires more than an old one. Nature has given to young animals of every kind a disposition to activity; but the exercise must not

be violent. A great deal depends upon the manner in which it is given. To preserve the temper, and to promote health, it should be moderate, at least at the beginning and the termination. The rapid trot or even the gallop, may be resorted to in the middle of the exercise, but the horse must be brought in cool. If the owner would seldom intrust his horse to boys, and would insist on the exercise being taken within sight, or in the neighbourhood of his residence, many an accident and irreparable injury would be avoided. It should be the owner's pleasure, and is his interest, personally to attend to all these things.'

Watering and Feeding.

A horse should be exercised a little after being watered. He should on no account be allowed to drink when heated, particularly if heated to the extent of perspiring. The only refreshment allowed in these circumstances is a rinsing of the mouth, and the muzzle may be washed and relieved of froth. When not permitted to take water of his own accord in the stall, let him be offered a pail three or four times a day; and after drinking copiously at either a pail or pond, he may be trotted or gently cantered, the motion being generative of heat, and at least preventing any chill.

Horses are fed on different materials in different countries; but principally on the various kinds of grasses and cereal grains. The Germans give them feeds of brown bread while on a journey; in India, rice and spices are employed for their diet; in England, the chief articles of food are oats and hay, with inferior proportions of beans, peas, cut straw, and bran. The quantity, and also the nature of the food, will depend on the habits of the animal, and the work to which he is put. If the work be hard, he must be fed to a considerable extent on oats and beans, which are more nutritious than most other articles in use; but if the work be light, a lighter diet of hay, with perhaps only a small quantity of oats, will suffice. The stomach of the horse being small, he cannot eat much at a time; and it is always preferable to feed him often, and at regular intervals, than to offer him large feeds at irregular periods. There is another reason for offering small feeds: the horse nauseates food which he has blown upon, or previously touched, and will accordingly reject it if offered a second time, or allowed to stand beside him. For various reasons, therefore, it is better to give him only a little at a time, so as to leave none behind. If the animal be a poor feeder, or apt to waste his food, greater care must be taken in this respect.

Oats ought to be sound, old, and dry. If musty, reject them. In almost all cases, it is preferable to have them bruised; for by this they are more easily digested and nourishing than if left whole. It is now customary to mix oats with chaff composed of the cuttings of clover or meadow-hay, and the straw of wheat, oats, or barley. In some stables, a machine is kept to cut these materials. The length of the cuttings should be about half an inch. Bruised oats have a tendency to scour the animal; but the admixture of chopped stuff counteracts this quality.

Of hay, clover, and meadow-hay, little need be said. They should be sound and sweet-flavoured, without any mustiness. The hay should, if possible, be a year old, and well saved for use in an adjacent stack. Some horses are fond of peas; but they require to be given with caution, as they are apt to swell in the stomach. Almost all horses are inordinately fond of carrots, which, when administered in small quantities, do not purge the animal, and improve his coat. A respectable authority states, that 'for agricultural and cart horses, eight pounds of oats and two of beans should be added to every twenty pounds of chaff; and thirty-four or thirty-six pounds of the mixture will be sufficient for any moderate-sized horse [daily] with fair or even hard work.' In this estimate, no hay is supposed to be given. When the horse is fed on the last two articles, hay and oats, four feeds, or nine or ten pounds of oats per day, will be a fair allowance during winter, and in the case of moderate work; but in summer, half the quantity, along with a proportion of green herbage, will suffice. Many gentlemen follow a general rule of allowing twelve pounds of oats per day to each riding-horse, and this is given in three or four meals. A pony, having but moderate work, will be well fed on six pounds of oats per day with a fair proportion of hay. Latterly, sago has come into use as an article of horse-diet; and we believe it is tolerably nutritive, and may be employed to a certain extent to supersede oats, or to be mixed with them. It should be partially softened by preparation.

THE DISEASES OF HORSES.

In consequence of the general mismanagement and ill-treatment of horses, they are exposed to a number of formidable diseases. Those of most frequent occurrence are inflammation of the lungs, broken-wind, inflammation of the bowels, and certain illnesses of the feet and legs. Referring our readers to larger works on the horse for full information on these diseases, and recommending all unskilled persons at once to hand over their horse to a veterinary surgeon when unwell, we propose only to give a few hints as to the best means of prevention. The institution of schools of veterinary surgery, at which the anatomy, peculiar nature, and diseases of horses are explained by men skilled in this important department of science, has been a powerful auxiliary in improving the qualities of horses, preserving their lives, and saving them from much needless distress.

Inflammation.

The more ordinary inflammation is that of the lungs, and is caused by sudden changes of temperature; it is, in reality, the grand disorder of the horse, and its effects are only paralleled by those of pulmonary consumption in the human species. Already we have spoken of the great impropriety of exposing horses, while heated, to cold draughts. Allowing them to stand any length of time in the open air, in cold or moist weather, is equally objectionable, and positively cruel. Inflammation of the lungs, however, will arise from various causes besides cold, and these have engaged the most serious attention of veterinarians.

In an essay for which the prize was awarded several years ago by the Highland Society to Mr M. Milburn, Yorkshire, the essayist observes: 'The post-horse, and such as are required to perform fast work, are more liable than heavier draught-horses to diseases of the brain, the

nerves, and the lungs, simply because their work consists of rapid and powerful exertion; the farm-horse, the animal of long and steady exertion, to gripes, inflammation of the bowels, and stomach-staggers—results, as I shall presently shew, of a management unsuited to the character of the labour we require from them. The stomach of the horse is remarkably small—smaller in proportion to his size, and the quantity of food he requires, than any other domestic animal. Nature intends for him a supply of nutritious food, and that *at short intervals;* wherein he materially differs from the ox, whose capacious stomach will contain food which will not be digested for hours. The post-horse, the hunter, and the carriage-horse, have food of the most nutritious description, and the time during which they are worked is necessarily short, owing to the extreme exertion required; they return to their food, and although their appetite may for a time be impaired, and their stomach and bowels affected by the general debility of the system, yet they recover their tone as soon as the rest of the frame admits of their taking food. The farmer's horse, on the contrary, has food of a less nourishing nature; his rack is filled with straw, or at best with clover; the ploughman rises early, gives him a feed of corn, and leads him to his work, where he continues for seven, eight, and even nine hours, and his whole day's work is completed before he is allowed to eat. We do not find the ox, worked under similar circumstances, so affected in the stomach and bowels, simply because his capacious stomach, when filled, requires many hours to empty; while, as we have seen, it is different with the horse. Debilitated and hungry, the horse returns, and his rack is plentifully supplied, and a good feed of corn given him, and he is left to himself: he eats voraciously, half masticates his food, loads his debilitated stomach, and his digestive organs are weakened, and permanently injured. This course is repeated—a habit of voracity is acquired; and at no very remote period the food lodges and obstructs the pyloric orifice—the passage from the stomach to the bowels—fermentation ensues, gas is evolved, the stomach is distended, he grows sluggish and sleepy, drops his head upon his manger; or he is delirious, and evinces that the sympathy which exists between the stomach and the brain has excited the latter organ; he rolls, paws, and is seized with convulsions; at length he expires, and he has died of stomach-staggers. The half masticated food has irritated the bowels, extra exertion of the muscles has been required to propel the fæces to the rectum, and colic or cramp (spasms) of the bowels has followed; or a course of continued irritation, or of continued colic, or both, has ended in inflammation of the bowels. I remember a beautiful farm-horse, which, owing to the distance of part of the farm to which he belonged from the buildings, was worked the long hours described, and finished his day's work before his bait. He was constantly subject to attacks of the gripes, which were subdued; but he died of stomach-staggers. The same stable, then so often subject to diseases, is now, by a change in the system, completely free from them. Another case, however, occurred: a beautiful compact little mare was constantly afflicted by colic; she eventually died of inflammation of the intestines.

'There are other parts of the management to which horses employed in agriculture are subject, which induce diseases of the bowels. For instance, a boy returning from work, with heated and sweating horses, to save himself trouble, allows them to drink copiously at some pool or stream he passes. Suddenly one or more of the horses exhibit symptoms of gripes; they suddenly lie down, roll about, look at their sides, rise up, seem relieved, and again speedily relapse; the sudden application of the cold water has produced spasms in the bowels, through which it has passed. This is neglected, or perhaps gin or whisky, aided by pepper, is administered as a remedy, and severe and general inflammation of the bowels is the result: this is mistaken for another attack, and again the poison is administered, and the inflammation increased, and death follows. The horse of heavy work, too, is longer exposed to the inclemencies of the weather than the animal of light work. In the former, the rain is allowed to fall upon him for hours, and then *to dry upon his back:* the sympathy between the skin and the alimentary organs is known to every groom; obstructed perspiration, and consequent irritability, is conveyed from the one to the other, and disease is the consequence. It is true the latter is also partly exposed to the rain, but for shorter periods, and the wisp and brush are liberally applied when he enters the stable; a determination of blood takes place to the skin, perspiration is promoted, and disease thus prevented.

'Of the best means of preventing these diseases in farm-horses we will now treat: we have attributed the peculiar liability to them in farm-horses to mismanagement, with the exception of certain instances of peculiar formation of the animals; and although the farmer must necessarily work his horses longer hours than the horse of rapid work is capable, there is no necessity for depriving the animal so long of food. No horse should work more than five or six hours without a bait. If we examine the history of the stables of large farmers, whose fields necessarily lie at a great distance from the buildings, and where they are worked long in consequence, and compare it with that of small farmers under the contrary circumstances, we shall find a striking difference as respects the health of the animals. The case referred to above strikingly illustrates the truth of this observation. But it may be asked—How is it possible to bait the animals so far from home? The difficulty seems to be in procuring food upon the spot; for if this is not done, the precaution will be neglected, and at anyrate the land will be occupied by it. This, however, may be remedied. In the case, for instance, of a field intended for turnips, which has to be worked during the spring, a part of it, half an acre, or in proportion to the size of the field, may be sown with winter-tares, a few of which may be mown off, and given to the animals green, without carrying them from the field, interfering with any crop, or wasting any time in carrying the horses to a distance. If the field be intended for summer-fallow, the spring tare will answer, and which may be used in the same manner, instead of allowing the poor animals greedily and indiscriminately to crop the leaves of the hedges at every turning, from the impulse of hunger. There is another easy way of baiting, which some carters adopt, and which might be applied

to the farmer's horse, especially when carting. It consists in securing a bag containing corn over the animal's mouth and nose, by a string, which passes over the poll, and is locally denominated a "nose-bag," or "horse-poke," and which should be removed when he has finished his feed. To prevent the effects of the wet upon the skin, an unexpensive glazed cloth may be thrown over the horse's back, and secured to the collar and traces. This may by some be considered very troublesome; but it will be found that when it is once begun, it will be considered no more trouble than carrying the rest of the harness; and if disease is prevented, the trouble amounts to nothing. To counteract as much as possible any habits of greedy feeding which the horse may have acquired, his corn should be mixed with chopped straw, or chopped clover, which will secure its proper mastication, and prevent many troublesome complaints, as well as render all the nutrition of the food available. These may be substituted by an admixture of clean chaff with corn—a plan which is pursued in a farm-stable with which I am acquainted, and is found a useful practice. It would save the animals much time in eating if all their food was chopped, and perhaps steamed; but on this subject we have not sufficient data to determine with accuracy.'

The cure, it has been hinted, must generally be left to the veterinary practitioner, whose chief object should be to empty the stomach. In severe cases, an ounce of laudanum and a drachm of pounded ginger, in a quart of warm ale, may be used with probable success.

Broken-wind.

When the breathing of a horse is rapid and laborious, it is said to be *thick-winded;* and when it breathes irregularly, the inspiration taking one effort, and the expiration two, it is called *broken-wind.* Inflammation of the lungs from cold is a cause of thick-wind, the condition of these organs preventing the full action of the air-tubes. The chief cause of broken-wind is sharp work after over-feeding—causing the animal to run while the stomach is full. Grossly fed, badly managed horses, are hence most subject to the complaint. Carriage and coach horses are seldom broken-winded, unless they bring the disease to their work, for they live principally on corn, and their work is regular, and care is taken that they shall not be fed immediately before their work. The farmer's horse is the broken-winded horse, because the food on which he is fed is bulky, and too often selected on account of its cheapness; because there is little regularity in the management of most of the farmer's stables, or the work of his teams; and because, after many an hour's fasting, the horses are often suffered to gorge themselves with this bulky food; and then, with the stomach pressing upon the lungs, and almost impeding ordinary respiration, they are put again to work, and sometimes to that which requires considerable exertion. The agriculturist knows that many a horse becomes broken-winded in the straw-yard. There is little nutriment in the provender which he there finds; and to obtain enough for the support of life, he is compelled to keep the stomach constantly full, and pressing upon the lungs. Some animals have come up from grass broken-winded that went out perfectly sound. The exact nature of the disease is unknown. It appears, however, to consist in a paralysed condition of the bronchial tubes and remoter air-cells, which renders expiration more difficult, and necessitates the double effort so characteristic of the malady.

'The cure of a broken-winded horse no one ever witnessed; yet much may be done in the way of palliation. The food of the animal should consist of much nutriment condensed into a small compass; the quantity of oats should be increased, and that of hay proportionably diminished; the moistening of the hay is also usually beneficial; the bowels should be gently relaxed by the frequent use of mashes; water should be given sparingly through the day, although at night the thirst of the animal should be fully satisfied; and exercise should never be taken when the stomach is full.' Under such management, and at slow work, a broken-winded horse will often remain serviceable for years.

Curb—Bog-spavin—Bone-spavin.

The hock-joint is particularly liable to derangement, so as to render the animal unsound. One of these affections is called *curb*, which arises from over-exertion of the ligaments, and takes the form of an enlargement a few inches beneath the joint of the hock. A more serious complaint of the hock is the *bog-spavin*, which takes place from over-exertion, and is an inflammation in the vesicles containing the lubricating material for the joint. This disease is almost incurable; and the poor animal is in general only fit for ordinary and moderate work all the rest of his life. The *bone-spavin* is a still more formidable disease. It is an affection of the bones of the hock-joint, caused by violent action, or any kind of shoeing which throws an undue strain on certain ligaments, and deranges the action of the bones. A bony deposit takes place, the joint is stiffened, and the consequence is a lameness or stiff motion in the hind-legs. Blistering as a counter-irritant, and rest, are the principal remedies prescribed for this complaint; but the best thing of all, so as to *prevent* not only this, but all other similar complaints, is never to overload the horse, or put him, especially before he comes to his full strength, to any violent exertion.

Physicking.

Horses, even when attended to with the greatest care, occasionally get into a condition which requires physic—that is, purgative medicine; as, for example, when they have been too long on hard food, and require a laxative; when they get into a heated state of body from constant high-feeding; when their bowels get overloaded or disordered; or when they are getting too fat. The most simple laxative is a *bran-mash.* Bran is put into a pail, and softened with boiling water; when cooled sufficiently, it is given to the animal as the last feed at night, instead of corn or hay. About half a pailful is a dose. Horses used by commercial travellers or others during the whole week, and fed on corn, are indulged in a mash on Saturday night; and this, with the rest on Sunday, keeps them in good condition. When a working-horse is lamed, or becomes sick, and must remain idle for a few days, he requires to be relieved by a dose of physic.

Generally, this consists of from four to seven drachms of Barbadoes aloes, powdered, and formed into a round moistened mass, fit to be swallowed. It requires to be administered by a skilful groom, who will push it over the throat adroitly, without alarming the animal. Sometimes the powder is mixed with a little Castile soap. An hour or less after taking physic, a bran-mash should be given, and then the horse be gently exercised. On his return to the stable, he may be offered a drink of water from which the chill is taken, or as warm as he will take it.

We should consider it imprudent to offer any further explanations of the materia medica of horses; and again recommend all unskilled or but partially instructed persons not to attempt doctoring their horses themselves, but to obtain at once the advice of a veterinary surgeon.

ADVICE IN PURCHASING A HORSE.

The purchasing of a horse is ordinarily a matter of very serious difficulty, in consequence of the proverbial trickiness of dealers, and the many defective points in the animal's constitution, which cannot be seen with all the care that may be bestowed. In offering any hints on this important particular, we must refer to the instructions of authorities whose testimony is worthy of confidence. Mr Stewart has written a valuable little manual, entitled *Advice to the Purchasers of Horses*, which should be in the hands of all who have frequent occasion to make purchases. The following are a few of his admonitions:

'In buying a horse, one of the chief requisites to be attended to is the degree of nervous energy which the animal possesses; and it is the union of this energy with good conformation that makes many horses invaluable. Its absence or presence, however, is not likely to be discovered by the purchaser without a trial; and to avoid disappointment in this respect, it is therefore advisable to obtain one prior to purchase. The horse should be set to the work he will be called on to perform; and if he is intended for the saddle or single harness, he should have no companion on his trial, for many animals work well in company that are downright sluggards when alone. Some horses have an unpleasant way of going, or are difficult to manage, or have some vice which is only displayed when at work: these are so many more reasons for having a trial prior to striking a bargain. But if that cannot be obtained, some sort of conclusion regarding the animal's spirit may be drawn from his general appearance. The way he carries his head, his attention to surrounding objects, his gait, and the lively motion of his ears, may all or each be looked to as indicative of "bottom," or willingness to work. It is only, however, in a private stable, or in that of a respectable dealer, that these *criteria* can be depended upon; for in a market-place, the animal is too much excited by the cracking of whips, and the too frequent application of them, to be judged of as regards his temper. Neither must the buyer be thrown off his guard by the animation which horses display at an auction, or on coming out of the stable of a petty dealer; for it is a fact, which cannot be too well made known, that there are many unprincipled dealers who make it their business, before shewing a horse, "to put some life in him"—that is, they torture him with the lash, till, between pain and fear, the poor animal is so much excited, as to bound from side to side with his utmost agility at the least sound or movement of the by-standers.'

This writer continues, in relation to the head and other parts of the animal: 'The head, as being a part not at all contributing to progression, should in the saddle-horse be small, that it may be light; the nostrils expanded, to admit plenty of air, and the space between the branches of the lower jaw, called the channel, should be wide, that there may be plenty of room for the head of the windpipe. In the draught-horse, a heavy head is not, so far as utility is concerned, an objection, for it enables him to throw some weight into the collar; and hence, excepting its ugliness, it is rather an advantage, if he is used entirely for draught. But it makes the saddle-horse bear heavy on the hand of the rider, makes him liable to stumble, and, when placed at the end of a long neck, is apt to wear out the fore-feet and legs by its great weight. The neck of the saddle-horse should be thin, not too much arched, and rather short than long, for the same reason that the head should be light; and in the draught-horse it may be thick, stallion-like, and sufficiently long to afford plenty of room for the collar, and for the same reason that the head may be large in this animal. The windpipe should be large, and standing well out from the neck, that the air may have an easy passage to and from the lungs. A horse intended to be used for the miscellaneous purposes of carriage and draught, should have a head and neck neither too light nor too heavy.

'That the saddle-horse may be safe, and have extensive action, it is necessary that the withers be high. This advantage is indicated by the horse standing well up before; and it is usual, in shewing a horse, to exaggerate the height of the forehand by making him stand with his fore-feet on a somewhat elevated spot. A horse with low withers appears thick and cloddy about the shoulder. In the ass and mule, the withers are very low, and the shoulders very flat, and this is the reason why they are so unpleasant to ride, and why it is next to impossible to keep the saddle in its proper place without the aid of a crupper. High withers, however, are not essential to the racer or the draught-horse. The former does all his work by leaps, and that is performed best when the horse stands somewhat higher behind than before: neither are high withers necessary to the draught-horse; but in the roadster, they are as important as the safety of the rider is, for a horse with a low forehand is easily thrown on his knees. In the draught-horse, this tendency towards the ground is obviated by the support the collar affords.

'The chest should be deep and wide in all horses, but especially so in one intended for quick work, in order that there may be plenty of room for the play of those important organs, the lungs.

'The back should not be too long nor too short; for though length is favourable to an extended stride and rapid motion, yet it makes the horse weak, and unable either to draw or carry any considerable weight. On the other hand, if the back be too short, the horse's action must be confined; and short-backed horses, in

general, make an unpleasant noise when trotting, by striking the shoe of the hind-foot against the shoe of the fore one; and though they are in general very hardy, and capable of enduring much fatigue, and of living on but little food, yet a back of middling length is better by far than one immoderately short or long. The back should be nearly straight.

'In the saddle-horse, and where safety is desirable, the position of the fore-leg is worthy of attention. It should be placed well forward, and descend perpendicularly to the ground, the toe being nearly in a line with the point of the shoulder. The pasterns should neither be turned in nor out. When they are turned inwards, the horse is in general very liable to cut the fetlock-joint by striking the opposite foot against it. The draught-horse may be excused though he leans a little over his fore-legs, but the saddle-horse will be apt to stumble if he does so.'

Minute attention should be bestowed on the examination of the fore-legs and feet; these, in fact, are the great trying-points. If the feet be not round and full, so as to stand firmly and flatly on the ground, and if tender or thin in the hoofs, the animal is not to be trusted for saddle-work. Mr Lawrence on this subject remarks: 'The feet of saddle-horses, be they ever so sound and good in nature, detract greatly from the value of the nag, unless they stand even on the ground; since, if they deviate inward or outward, the horse will either knock or cut in the speed—that is to say, will strike and wound the opposite pasterns either with his toe or his heel; and if he bend his knees much, and is a high goer, will cut the inside of the knee-joint. Nature has been very favourable in the hinder hoofs, with which we have seldom much trouble; but there is, now and then, a most perilous defect in them—namely, when the horse is so formed in his hinder quarters that he overreaches, and wounds his fore-heels with the toes of his hind-feet.' The defect here spoken of will be observed to cause an unpleasant clattering noise in trotting. The fore-legs, from the knees downwards, should be clean made, sound, and flexible at the joints. Bad usage knocks up a horse, or founders him; and his legs, being in a kind of benumbed state, will either wholly or partially refuse to perform their office. By ease and physicking, the horse recovers; but his system has been shaken, and he is apt to come down. This is a fearful defect in a horse; for no one is for a moment safe on his back. Weakness in the fetlock-joint will also cause a horse to stumble and come down, and is therefore an equally serious defect. When the horse stumbles either through weakness or bad management, so as to come down on his knees, the likelihood is, that the knees are broken; and it is well known that wounds of this nature never heal over to resemble the original. The horse with broken knees is, in short, damaged for life, at least in as far as he is a marketable commodity.

Horses are sold either with or without warranty. At sales at repositories, the terms of warranty are generally announced in a public manner; but when the sale is private, no warranty is binding which is not expressed in writing in the receipt. The principle that a price above £10 warrants a horse sound, is not now recognised as binding. The warranty, to be of any legal value, must be something different from a mere verbal understanding or illusory custom.

DUTY OF HORSES.

Draught.

The horse is equally willing to make himself useful as a beast of burden or draught; but his powers are best adapted for the latter, and particularly on a level road. The formation of his body does not suit him for climbing or going uphill with a load; and his strength is always exerted to greatest advantage when he can throw his centre of gravity forward as a make-weight. The amount of load which he can draw in a wheeled vehicle depends on the arrangement of the load to the pull. The pulling-point is across the shoulders, and the most advantageous method is, to make the line of traction proceed *direct* from the shoulders to the load—in no shape bent or distracted from its course. The load should be placed lower than the line of the shoulders, thus making the line of traction go by a straight slope to the seat of resistance. The load should not be at a greater distance than will allow freedom of motion to the hind-legs. If it be placed too low, a part of the power will be uselessly spent in upholding it.

According to the calculations of James Watt, the weight which a horse can draw, called a *horse-power*, is 1,980,000 pounds raised one foot high per hour, or 33,000 pounds raised one foot per minute. The weight is supposed to hang at the end of a rope passing over a freely-moving pulley. This calculation is based on considerations more favourable than those which usually attend horse-labour. There are, in reality, no rules to guide the imposing of loads on horses; for everything depends on the degree of friction on the wheels of the carriage, the nature of the road, and the strength of the animal in question. One thing is certain, that a horse always exerts his power better by himself than when yoked with others. The load which it requires four horses to draw unitedly, if divided, could be drawn with equal ease by three.

It has been said, in reference to the operations of Sir C. Stuart Menteith: 'If the employment of horse-wagons, weighing from twelve to thirteen hundredweights, were adopted in conveying coal through the streets of London, one horse would do the work of two: at present, four immense horses draw three chaldrons of coal, or four tons one hundredweight, in a wagon weighing perhaps two tons; so that the shaft-horse is obliged to draw a weight of six tons in turning out of one street into another.'

The power of draught of a horse depends on the rate at which he is compelled to proceed. He exerts his power to most advantage at a fair pull, when moving at the rate of from two and a half to three miles per hour. If he go at a greater speed, he is less able to draw. As a general rule, if the speed be doubled, the load should be halved; and if the speed be twice doubled, the load should be quartered; yet this will only hold as correct for short distances. Much work may be procured from a horse if he be impelled only for short stages. A horse in a stage-coach, running only five miles at a time, and then resting for a few hours, will last at least four times longer than

another horse of equal power which runs ten miles at a time. This is well understood by all stage-coach proprietors, and short stages have now almost everywhere superseded long ones. Such a fact should also be known to all private travellers. Whether employed in a gig, chaise, or for riding, the horse on a journey should take his day's work in two distinct stages—one in the morning, and another in the afternoon, when rested and refreshed. He should also, to remain in good condition, have a rest during the whole of Sunday. In journeying with light loads, a distance of from twenty to twenty-five miles is considered a sufficient day's task.

Riding.

The art of riding or equitation forms a regular branch of instruction, and is seldom well performed by those who have not been regularly taught; and nothing we can say can supersede the necessity of instruction by a master. It should be performed in that manner which is least calculated to oppress the horse and fatigue the rider, and which will be most secure for both parties. The first principle in horsemanship is, that the horse and his rider should act and react on each other as if governed by one common feeling. To attain this end, the rider must acquire the knack of balancing himself properly on the animal, and establishing the means of making himself understood through certain movements of hand and body. For full instructions in the art, see Walker's *Manly Exercises.*

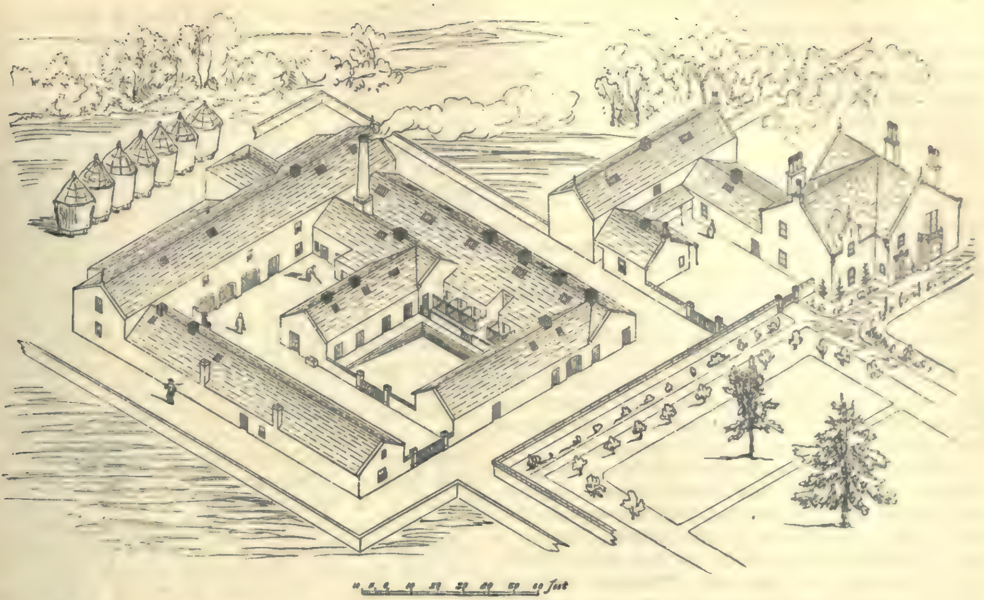
Riding, to one accustomed to it, is best performed with a curb and snaffle bridle; the curb, however, being only employed to bring the animal up by pressure on the mouth when occasion requires. As some horses have a much more delicate mouth than others, the nature of the bridle must depend on circumstances. In holding the reins, a union of firmness, gentleness, and lightness is the essential requisite.

Much may be done to animate a horse, either in riding or drawing, by addressing a cheerful word to him, instead of the lashing and scolding with which he is too frequently visited. If a horse requires correction or urging by the whip, he should only be touched lightly behind the girth and saddle, never on any account on the head or on a fore part of the body. We have frequently seen riders so lost to humanity as to whip their horses when restive over the head and ears. Should a horse attempt to baffle his rider, he must be pressed by the legs, urged lightly with the spur, and kept in his proper track, but not drawn up with the curb or terrified by abuse.

The most common pace in road-riding is the trot, which, in effect, is a rapid walk, and most difficult for a rider to perform with address and a small degree of fatigue to himself. In slow trotting, the body should adhere to the saddle, and when it becomes fast or rough, the body may be raised at the proper moments to ease the jolting. This rising of the body, however, is to be a result of the horse's action, not an effort of the rider. The proper method is to rise and fall with the leading foot, the body rising from the seat when the foot is elevated, and falling when it sinks.

In the course of either slow or fast riding, the horse may trouble his rider by plunging, shying, or restiveness. If he kick and plunge, sit upright, hold on by the legs, and do not vex him by any lashing; when let alone, he is not long in coming out of his freak. When he shies, or flies to one side, as if afraid of something, press him on the side to which he is flying, keep up his head, and bring him into his track. Pressing both legs against his sides will generally keep him from running backward. When he becomes restive—that is, turns round, and has a disinclination to go in the way he is required, the rider must keep him in his track by dint of pressure, a touch of the spur, and the hand. If he has been accustomed to spurs, and finds that your heels are not provided with these appendages, your case is very hopeless. We must allow Walker to point out the course to be pursued with a restive horse. If he persists in turning round, the rider must continue 'to attack his unguarded side, turn him two or three times, and let the heel and spur, if necessary, assist the hand, before he can arm or defend himself against it. If he still refuse to go the right way, the rider must take care that he go no other, and immediately change his attack, turning him about and reining him backward, which the horse is easily compelled to do when he sets himself against going forward. In these contests, the rider must be collected, and have an eye to the surrounding objects; for restive horses try their utmost to place their riders in awkward situations, by sidling to other horses, carriages, the foot-pavement, the houses, &c. In this case, the rider, instead of pulling him from the wall, must bend his head to it, by which his side next the wall is rendered concave, and his utmost endeavours to do injury are prevented. The instant, therefore, that the rider perceives his horse sidling to any object, he must turn his head to that object, and back him from it. There are some horses who fix themselves like stocks, setting all endeavours to move them at defiance. There, happily, their defence can in no way endanger the rider. It must, however, be converted to punishment. Let them stand, make no attempt to move them, and in a short space—frequently less than a minute—they will move of themselves.' The same author recommends the rider to remain perfectly cool in all these awkward circumstances. 'When passion,' he observes, 'possesses the rider, it prevents that concord and unity taking place which ever should subsist between the rider and his horse. He should always be disposed to amity, and never suffer the most obstinate resistance of the horse to put him out of temper.'

Neither in the above section nor elsewhere have we said anything of the accoutrements of the horse, as every article of this kind must be left to the taste of the party concerned. The harness made by all saddlers is now handsome, convenient, and durable, and so well calculated for the comfort of the wearers, that it would be superfluous to say anything respecting it, further than to recommend that it be always kept clean and glossy, and that it do not gall or press unduly on any part of the animal's body.



Isometric View of Open-courted Steading for Dairy-farm of 250 Acres.

CATTLE—DAIRY HUSBANDRY.

NEXT to the horse, the cow is justly valued as the most useful animal that man has been able to domesticate and retain permanently in his service. The ox tribe, of which it is the female, belongs to the order *Ruminantia*, in the class *Mammalia*—these terms implying that the animals ruminate or chew their food a second time, and have mammæ, or teats, with which they suckle their young. In the ox tribe (*Bovidæ*), there are different species, all more or less varying from each other. Of the domesticated ox (*Bos taurus*), the varieties, from the effect of climate, with attention to selection and care in feeding, are now very numerous. The ox, in one or other of its varieties, has been domesticated and carefully reared from the earliest times, for the sake of its labour as a beast of draught, for its flesh, or for the milk of its female. In some parts of Asia, the ox is used for riding and for carrying burdens, as the camel is in the East, or the packhorse in Europe. In ancient Egypt the ox was raised to the rank of a divinity; while in India, at the present time, he is, by several of the Hindu castes, held as an object of extreme veneration.

The domesticated species of the family, common to the British Isles and Europe generally, is, in all its varieties, materially altered from its wild parentage. Influenced by climate, peculiar feeding, and selection in the domesticated state, its bony structure is diminished in bulk, its ferocity tamed, and its tractability greatly improved. The ox in a wild state is kept at Hamilton Palace, and also at Chillingham Park, Northumberland. Our observations in the present sheet will refer chiefly to the domesticated ox, on which very great changes have been effected by domestication. The most remarkable of these is an increased capacity in the female for giving milk. In a wild state, the udder is small; but when domesticated for the sake of its milk, and the lactic fluid is drawn copiously from it by artificial means, the lacteal or milk-secreting vessels enlarge, and the udder expands, so as to become a prominent feature in the animal. In this manner, by constant attention, the economy of the cultivated species has been permanently altered, and rendered suitable to the demands which are made on the cow. Yet it is important to remark, that those milk-yielding powers are not equal in the different varieties or breeds. Some breeds, from the influence of circumstances which it is here unnecessary to inquire into, give a large quantity of milk; while others yield less, but of rich quality. The quantity and quality of the milk depend, however, on various conditions. The principal are, the age of the animal, the feeding, the housing, &c. In the more highly cultivated breeds, the variations in the flow and in the quality of the lactic fluid in different animals are often remarkable. The cause or causes are usually extremely difficult to account for. In general, near large towns, where the demand for milk is considerable, the object of dairymen is to keep cows which will give a large quantity.

VARIETIES OR BREEDS.

The breeds of cattle throughout the United Kingdom vary in different districts, from the small hardy varieties of the Shetland and Orkney Isles, and the north and west Highlands, to the handsome and more bulky breeds of the arable districts.

Short-horn.

The *Short-horn or Teeswater* breed is considered of great value, both for milking and feeding. Those of the best strains of blood are large, well proportioned, broad across the loins, chine full, legs short, head small and handsome, neck deep, in keeping with the size of the body, skin thin and mellow, colour generally white or red, or red and white mixed, or roan. The flesh of the Short-horn is thick and close-grained, the lean and fat well intermixed, and retains the juices. From this circumstance, it is in request for victualling ships going on long voyages.

Authorities are at variance with reference to the milking qualities of this breed; some asserting that, unless the climate and food are very favourable, they are seldom good milkers, having a greater tendency to produce fat than milk; others, again, maintaining that any deficiency in their milking capabilities arises not from the peculiarities of the breed, but from the neglect of breeders to develop the property of giving milk, their attention being chiefly bestowed on the development of flesh and fat. The dairies in London and the neighbourhood of the metropolis are generally occupied with cows of this breed, or of crosses of the Short-horn. As grazing-cattle, they stand first in point of value. Their 'aptitude to fatten,' says a writer in the *Cyclopædia of Agriculture*, 'and the amazing weight and maturity of carcass to which they attain while their age is only reckoned by months; their symmetrical form, rich colour, and quiet temper,' have 'secured to them the pre-eminence over all other cattle. So thoroughly, indeed, do they meet the requirements of our arable husbandry in its highest modes, that we may warrantably expect, at no distant day, to find them recognised as *the one appropriate breed* of the lowlands of the kingdom.' Animals of this breed generally realise high prices.

The following is the result of four auction sales during the past year (1872):

Name.	No. of Lots.	Highest price. Guineas.	Lowest price. Guineas.	Average. £	s.	d.
Earl of Dunmore (selection)	54	1200	40	242	18	9
Messrs Harward and Downing	61	1650	30	253	8	2
E. Bawley (selection)	30	900	30	153	1	9
T. E. Pawlett (deceased)	40	550	40	195	18	7

At Lord Dunmore's sale, three Oxford heifers realised 3070 guineas. Extreme prices may be a source of speculation, but it is difficult to estimate the value of cows when their bull-calves sell readily for a thousand and twelve hundred guineas each, and a three-year-old bull realises £1732, 10*s.*; or when yearling bulls are let from two to three guineas each for the season. Equally high prices are obtained in Canada and the United States; indeed, not fewer than 26 animals of fashionable blood, as well as two young bulls of Booth blood, sent over by Mr Cochrane of Canada, have been imported to this country, within the last twelve or fifteen months, by the Earl of Dunmore and Mr Cheney.

The *Herefords* are to be found in perfection in the county from which the name is derived. They are of large size, with round cylindrical forms; the back and quarters broad; the head of moderate size; muzzle, broad; eye, large, prominent, and placid; horns of medium length, spreading outward and forward, with the points upward. The colour of the skin is almost uniformly deep red, with face white, and a white patch on the shoulder. Sometimes they have the ridge white, with belly and legs of corresponding colour. There is a strain of blood in which the animals are nearly white, with brown spots. For the dairy, the Hereford is the least productive of all the English breeds. The secretion of milk is at no time great, and the period of lactation is short. The cows generally suckle the calves, nearly the whole of which are reared. As animals for labour, the Herefords are admirably adapted, from their great weight in the yoke, their quick step, and their generally healthy constitutions, enabling them to undergo considerable fatigue. They are now little used for field-work; it is for their value as grazers that the Herefords are prized. When well kept, they are ready for the butcher at two and a half years, but are not generally slaughtered till they reach three to four years. The flesh is evenly laid on, and on the best parts, giving less coarse meat than perhaps any other breed. The flesh is highly esteemed; but when fully fattened, there is an excess of fat. Oxen of this breed always appear to great advantage at the Christmas fat shows. The Hereford has been long deemed the rival of the Short-horn, and, in the county of Hereford, is asserted to be superior.

The *Devons* occupy the third place in the English agricultural prize-lists. They are smaller and more delicate in structure than the Hereford. When reared on the richer lands of Somersetshire, the size is considerably increased. Specimens are met with nearly as large as Herefords. Their form is symmetrical; the head, small; the eye, clear and placid; the horns are finely tapered, spread out and upward; the horn is longer than in the Hereford. The colour of the Devon is deep red, without any white marking. As dairy-stock, they occupy a medium place, the milk being rather rich than abundant. There are dairies of Devons containing about 100 cows, which are stated to yield a large return of dairy-produce. As oxen for labour, the Devons are much prized; hardy, active, and quick steppers, they perform nearly as much work as ordinary farm-horses: the want of weight, however, operates against their working in pairs. As beef-producers, they are inferior to the Hereford; the quality of the meat is indeed superior, but it is unequal. This is a general complaint against the Devon in the London dead-market.

The *Sussex* breed is somewhat similar in form, and identical in colour with the Devon; it stands higher, and is less symmetrical. It is inferior for the dairy, but nearly equals the Devon for labour. It is long in arriving at maturity; but when fattened, the beef is of good quality. As a breed, it is not equal to the Devon.

The *Suffolk and Norfolk* polled breed is supposed to be descended from the polled Galloway. They are of medium size, somewhat deficient in symmetry, but are roomy and wide-set. The

colour is dark red to yellow. The milk-vessel is large, generally well placed. The Sussex and Norfolk are much esteemed for their milking properties. There are also horned breeds almost indigenous to these counties. The colour is similar to the polled breeds, but they are inferior as milkers.

The *Long-horn or Lancashire* was at one time much sought after, especially after its improvement by Robert Bakewell. This breed is now almost wholly superseded by the Short-horn. The Long-horn is distinguished by the length of its horns, which are usually curved in the form of a half-circle, and pointed downward. The length and general rotundity of the body, with the large sizes they attain, give this breed a fine appearance. Late maturity, with their inferiority as milkers, has caused the breed to be neglected. In some parts of Ireland, and in the counties of Oxford and Derby, there are breeders who still maintain the Long-horn pure.

The *Alderney* is the most esteemed of the Channel Island cattle. They are delicate in form—colours varying from light red to fawn and dun—generally with white intermixed. The head is long and handsome; eye, large and prominent; horns, short and crumpled. As dairy-stock, they have been much lauded, particularly for the quality of the milk. One or two Alderney cows in a dairy are stated to impart a richness of colour to the butter. Such is the demand for cows of this breed, that it is believed a much greater number is annually sold in England than the Channel Islands produce. As the same breed exists in a part of Normandy, a portion of these may swell the number of the Alderneys sold in England. Dairymen in Scotland believe that either the climate of Scotland is too cold for the Alderney, or the qualities of the breed have been exaggerated. Where tried, they have seldom given much satisfaction.

In Wales, there are various breeds, but a family likeness pervades the whole. The most common are black in colour, of medium size, with the body long. The horns are of medium length, white, with black points, and pointed upwards. Like mountain breeds generally, they are active, hardy, and do not reach maturity till an advanced age. They usually stand well to the pail, but are not much esteemed as dairy-stock, except by cottagers. For labour, the Welsh oxen are only excelled by the Devon. Their hoofs are well adapted for travel, resisting the tear and wear of the most flinty and gravelly soils. In the counties bordering on Herefordshire, the cattle resemble somewhat the Hereford in form and colour, but are smaller, with less aptitude to fatten. The Pembroke and Glamorgan are the most esteemed. The former are generally dark brown, with white ridges. As milkers, both are superior to the Hereford. The Welsh cattle are much esteemed by the grazier. Droves of black Welsh may be observed grazing in fields over the greater portion of the southern counties of England; they are usually purchased in the Welsh markets at prices which may be considered moderate when contrasted with those paid for Herefords or for Short-horn crosses.

The *Ayrshire* is generally considered the most valuable for dairy purposes. It is of medium size; the horn is small, short, and bent inward, sometimes pointing upward. The body is long and low set; skin, thin, loose, and soft to the touch; the head, long and narrow at the muzzle; eye, large and lively, sometimes with a certain expression of wildness; the neck, long, and slender in the cow, with little muscle; the shoulder, sharp; the fore-quarters, light; ribs, well sprung; hind-quarters, long, wide, and deep; back, straight; legs, short; the bones, small, but joints somewhat loose and open. The udder is generally capacious, placed forward on the belly, and not extending backward beyond the buttock; the teats are wide apart, and generally small. To adapt them for the inferior pastures which is the character of nearly all dairy-farms in the west of Scotland, the young stock is kept in such a way as to stint them in growth. The Ayrshire, when reared in Ireland, or when treated liberally at home, is found to increase considerably in size; and if this were desired, by attention to feeding and selection, they could be reared to nearly double the weight generally esteemed best for an Ayrshire cow. The heifers usually produce at little beyond two years, and are retained for the dairy till they reach seven or ten years. As beef-producers, the Ayrshires do not occupy a high place. When a Short-horn bull, however, is used, a very superior animal is produced for feeding purposes. This system is pursued by many farmers in the west of Scotland with great success, the stock being fattened off at two or two and a half years old, and realising nearly £1 a month for keep. The Ayrshire cow is more widely spread over Scotland than any other. It prevails over nearly the whole of the west, from Wigton to Ayrshire. It is exported to most continental states—Russia, Denmark, Sweden, France, &c.

Polled breeds.—Galloway, Angus, Aberdeen, &c. are peculiar to Scotland. The *Galloway* extends over a portion of the Border counties in the west

Polled Angus Bull.

of the island—Cumberland, Wigton, Dumfries, &c. and is named from the district of *Galloway*. In several of the south-eastern counties of Scotland, polled cattle are also found. They are there known as the Angus and Aberdeen polled. Fife, Kinross, and other counties produce some polled animals; but the Galloway, Angus, and Aberdeen polled cattle are the most generally esteemed. The polled cattle that are reared in the east of Scotland, owe much of their present high character as beef-producing animals to several breeders, particularly to the late Mr Watson of Keillor, Mr W. M'Combie, M.P., Mr Alex. Bowie, Mains of Kelly, and others, who,

by a long course of selection, have increased their size, and given them more symmetry, and greater aptitude to fatten. The above is a representation of a Polled Angus Bull which was reared by Mr Watson, and obtained the first prize at the Highland Society's meeting at Edinburgh in 1848. The polled Scots have all a family likeness; and the difference of climate and mode of treatment in the west and east of Scotland account in part for the rougher coat of the Galloway. The polled Angus and Aberdeen are of larger size than the Galloway—nearly equalling the Short-horn; body, long and deep, but somewhat flat on the sides; skin of medium thickness; hair, short and glossy. The most esteemed colour is black. Occasionally, the udder and a portion of the belly are white marked. As milkers, the improved polled are not remarkable. As cattle for the yoke, they are equal to any British breed, being agile, quick-steppers, and hardy. They maintain their procreating powers to a longer period than any other British breed. There are several instances on record of cows breeding above the age of twenty years, and producing upwards of twenty calves. It is as beef-producers of the highest quality and flavour that these polled breeds are so highly esteemed. As turnip-cultivation has extended in the districts where they are bred, almost the whole are now fattened in the north, and sent direct to the London markets, live or dead. A cross between a well-selected Short-horn and these polled breeds produces superior animals—size, early maturity, and quality of flesh being combined.

Highland cattle are much esteemed for the quality of the beef. The West Highland are the best known; they are found in the greatest perfection in Argyleshire and the Western Islands

West Highland Bull.

of Scotland. The above is a drawing of a West Highland bull, the property of Mr Duncan M'Naughton of Cashlie, which carried off the first prize at Edinburgh in 1848.* They are the most picturesque of all the British breeds; being handsome in form, straight from the head to the tail; body, round and symmetrical; legs, short and firmly set. The head is carried high; the forehead is protected by long shaggy hair; the eyes, large and lustrous; horns, long, spreading, and pointing upwards. The skin is usually thick, covered with a coating of shaggy hair, which protects them from the moist and stormy climate of their native hills. The colour is generally black; but they are to be found of all colours, from the light yellow or gray, almost white, to the deep yellow, red, and duns. The variety in colours heightens the picturesqueness of a herd of Highland cattle. They are at first small, but they increase rapidly when transferred to the rich pastures of the south, and are usually to be found grazing in the vicinity of gentlemen's seats. They are, as dairy-stock, distinguished for rich rather than for abundant milk. They do not continue fully profitable for the same period as the Ayrshire cow. The calf is generally suckled where extensive herds of West Highlanders are kept. This breed can exist on the coarsest herbage, and maintain its footing where no other would be safe.

Orkney cattle are of small size—colours black, or black and white. They are stunted in form, deficient in symmetry, and do not arrive early at maturity. The introduction of Short-horn bulls for crossing the native Orkney cow, will in a short time entirely change the character of the cattle sent from these islands to the mainland. Already the improvement in the stock sent out is very marked.

The Shetland Islands possess the smallest of the British breeds. When fattened, they seldom reach twenty-four stones of fourteen pounds. The colours are varied—brown and white, black and white, yellow, cream-colour, &c. As milkers, the Shetland cow, for the small quantity of food consumed, yields a large quantity of rich milk. The produce of a Shetland cow and Short-horn bull is more like the Short-horn than the Shetland; but they are generally disproportioned; they rapidly acquire flesh, and such crosses have been sold at £24 when under two years old. The cattle in Shetland, particularly during winter, resort to the sea-shore to eat sea-weed.

The *Kerry* is the only native Irish breed, and is confined to the western and more mountainous parts of Ireland. They are equally diminutive with the Shetland, are hardy, and can subsist on scanty fare. They are of various colours, but black is the most common in the Improved Kerry. They are well adapted for cotter holders in the mountain districts, yielding a considerable quantity of rich milk.

We have thus briefly treated of the breeds of cattle valuable in Great Britain. The most generally esteemed is the Short-horn. The Ayrshire is, however, best for the dairy; but the character of the climate, herbage, and local treatment, all influence the question of adaptability of breeds for particular districts or management. There are inferior animals of all breeds; and on fixing upon a breed, it is equally important to study to secure the best specimens, whether the object be for the dairy, or for the production of cattle intended for the shambles.

TREATMENT OF DISEASES.

Cattle are subject to various diseases, the result of improper treatment, or of causes connected with climate, which it is difficult to guard against. Many diseases can be traced to hereditary predisposition, such complaints generally proving the most obstinate to treat. By attention to feeding, shelter, and cleanliness, much can be done to promote a healthy condition. Cattle housed during

* We are indebted to the *Farmer's Magazine* for this and the Polled Angus Bull.

winter in well-ventilated byres, or in open sheds, and partially sheltered during summer, are usually healthy. Certain breeds are naturally hardy, and can be kept in the open air during the whole, or the greater part, of the year; such cattle are comparatively free of those diseases which are induced by exposure to cold and wet. Cows confined to byres during the whole season, and fed to repletion, to induce an abundant flow of milk, are very liable to diseases of the respiratory organs. Cattle, when being fattened, are also subject to inflammatory attacks. Veterinary surgeons usually prescribe bleeding and laxative medicines, and occasionally tonics. Recent experience in the treatment of inflammation of the lungs, particularly of pleuro-pneumonia, has tended to shake confidence in the curative effects of bleeding—except when taken at the very first stage—soothing rather than violent treatment being found the most successful. The owners of stock who can obtain, within a convenient distance, the services of an experienced veterinary practitioner, should employ such, rather than attempt to effect cures; but as certain complaints require prompt measures, the owners of cattle should be sufficiently informed, so as to be able to prescribe in such cases. All quacks and nostrums should be eschewed, and the curative power of nature relied on. To guide the non-professional man, the following description of the more common complaints of cattle is given:

Choking.—Cattle fed on bulbous roots, such as turnips or mangold, are liable to accidents from swallowing a portion of a root without its being previously sufficiently masticated to pass down the gullet into the stomach. The animal ceases to eat, and stands apart from the rest of the herd. Its distress, and the danger arising from the impacted substance, are in proportion to its size, form, and position in the gullet. When it is fixed near the top, the discharge of saliva, with efforts to regurgitate, is considerable. The head is occasionally extended, and the animal coughs frequently. Thus, the obstruction is sometimes moved, and relief afforded. When the substance is fixed near to the entrance of the stomach, the discharge of saliva, with eructations and coughing, are usually absent. In both cases, the breathing and pulse become accelerated, and unless the obstruction is displaced, there is considerable danger. The abdomen gradually distends, respiration becomes laboured, the pain increases, and the animal staggers, falls, and is suffocated. To prevent this, means are taken to force the substance downward into the stomach by the use of a probang. This, for an ordinary-sized animal, requires to be about six feet in length, elastic, with a cupped knob on the end, somewhat rounded at the edges. If the probang is hollow, it admits of the escape of the gas. To operate, at least two persons are required: one to hold the head of the animal; the other, to pass the probang into the gullet and press the substance into the stomach. Lard, butter, or oil should be rubbed on the point of the probang; the operator taking hold of the probang, the tongue held with the left hand, or the assistant taking the tongue to one side, the probang being passed along the roof of the mouth enters the gullet. As it reaches the impacted body, firm but moderate pressure should be used. In using the probang, the head should be elevated, and kept in a straight line with the neck. When the resistance is great, care should be taken not to force the end of the probang past the obstructing substance, or to injure the gullet. The substance once moved, there is seldom any difficulty in forcing it down into the stomach. As the length from the muzzle to the entrance of the rumen is about six feet, the probang should be passed downward within a few inches of its entire length. Upon displacing the impacted substance, the gases collected speedily escape, and the swelling falls. Sometimes it is necessary to puncture the rumen, to prevent suffocation. When this is done, the probang seldom requires to be used, as the obstructing body is gradually softened, and afterwards passes into the stomach. There are cases which can be relieved by giving the animal a dose of linseed oil or salt dissolved in water. But this treatment generally causes great pain to the animal, and there is some danger of a portion passing into the windpipe. Neither the probang nor the trocar should be used unless there appears to be considerable danger, as there is always a liability to accidents in operating. Animals which have once choked, are liable to become again affected; and for some time they should have the roots grated, or other food substituted.

Hove.—This disease occurs during all periods of the year, but is more common in spring and autumn. *Hove, hoven, swollen, dew-blown, clover-sickness, fog-sickness*, are various terms by which a distended rumen is known. Hove may arise from a rapid swallowing of the food, followed by the sudden repletion of the stomach; or it may proceed from a deranged state of the digestive organs. In either case, an evolution of gas takes place, which, if not speedily neutralised or discharged, causes death, generally by suffocation. Sudden changes in diet sometimes cause the disease. In spring, when animals which have been confined to courts or byres, are turned into fields where the herbage is luxuriant, with much clover, they are liable to swell. The liability is increased when the grass is damp from hoar-frost, dew, mist, or rain; also when there is a breeze more or less strong. In summer and autumn, the danger is increased when the cattle are placed upon second-crop clover, or allowed to graze on stubbles where the young clovers are advanced. Cattle getting into a field of beans or peas, when these are in a succulent state of growth, are liable to hove, particularly if the crop is damp. Cows which are removed from their pastures to be milked, are more liable to hove than cattle allowed to remain at pasture. Hove occurs occasionally during winter with cattle being fattened on turnip. Sometimes it is brought on by their eating Swedes which have been mildewed. A diet of bean-meal along with turnip generally increases the tendency to hove. The disease is frequently sudden in its attack, requiring to be combated speedily, or the animal may be lost. When the distention is not too far advanced, ammonia in water, or lime-water, should be given. Alcohol has also a good effect. Tar placed in an egg-shell, and passed by the hand over the throat, usually gives relief. One to two ounces of turpentine added to a quart-bottle of linseed oil, or to salt-water strong enough to float an egg in, generally reduces the swelling. One ounce of hartshorn, with four drachms of

powdered ginger in a pint of water, may be given, or two drachms of chloride of lime dissolved in a pint of water. If the distention is so far advanced that the animal is suffering considerable pain, and moves with difficulty, an incision into the rumen should be at once made, if relief is not afforded by medicine. The delay of a few minutes may prove fatal. An incision made with a sharp-pointed penknife, or with a trocar, will give speedy relief—the instrument being passed inward and downward to puncture the rumen. If a knife is used, a quill may be inserted in the wound. It is all-important to remember that the incision should be made on the left side, in that part of the abdominal cavity between the last rib and the point of the hook-bone. After the escape of the gas, the wound may be drawn together by a needle and thread, or piece of sticking-plaster placed on the part. The feeding afterwards should be restricted in quantity. If the patient exhibit symptoms of constitutional disturbance, aperient medicine may be given. One pound of common salt, or an equal quantity of Epsom salts dissolved in water, is the most suitable.

Abortion occurs more frequently in the cow than in any of the other domesticated animals. When one cow of a herd aborts, the case is usually followed by others; and the cow which has once slipped calf, is extremely liable to subsequent abortion at the same period of gestation. The character of the food (such as pastures or forage affected with ergot), fright, violent exertion (as in leaping fences), disease such as pleuro-pneumonia, and other causes, tend to produce abortion. When it takes place at the early stages of gestation, the constitutional disturbance is seldom great. Occurring, however, after the fifth month, there is considerable danger from inflammation, particularly of the womb. It is advisable to give sedative medicine: the best is common salt in the drink of meal-gruel. The food should be restricted, and the cow kept quiet, having been previously removed to a comfortable loose-house, apart from the other cows. Unless the animal is valuable for breeding purposes, it is advisable to fatten her off. If, however, it is determined to retain her, she should be got into good health previous to being served; and after she is pregnant, she should be kept quiet, fed regularly, but rather sparingly. Some practitioners recommend that within a few days of the period of the former abortion, four quarts of blood should be taken from the neck, and one ounce of the tincture of opium given each alternate day for a week. Keeping the animal in an open shed, and studying quietness, is the best security that the cow will reach the full time.

Puerperal Fever occurs frequently where the cow is in high condition, the flow of the lactic fluid considerable, and where parturition has been protracted and severe; it sometimes arises from overfeeding previous to, but in most cases after parturition. The cow, when affected, rises with difficulty—sometimes is unable to get up—the flow of milk is nearly, if not wholly suspended; and if relief is not speedily afforded, the animal dies. The first duty of the practitioner is to cause the bowels to act—one pound of Epsom salts, with two ounces of ginger, dissolved in water, should be given. This may be repeated in four hours. Clysters may also be tried. The udder should be bathed, and every effort made to induce a flow of milk. No time should be lost in calling in the most skilled practitioner.

Garrot in the udder sometimes follows severe parturition. It is, however, more frequently produced by an excessive flow of the lactic fluid to the udder previous to calving. It also arises from an unskilled or careless milker not drawing the teats regularly, nor emptying them completely. If the udder is much distended previous to parturition, the cow should be milked, and this for several days. Not only is this a great relief, but it tends to check that febrile condition incident to the constitutional disturbance. The indications of garrot are, a hot udder followed by a hard knot, after which pus and blood are mixed with the milk—this generally from one teat. Occasionally an abscess forms on the outside. Upon the first symptoms being observed, the cow should receive a handful of salt in gruel or in boiled food; repeat the dose every time the cow is fed till the bowels are acted on—and carefully restrict the quantity of food. The udder should be bathed with hot water, and gently rubbed, and the teats emptied. A little lard rubbed over the udder is also advisable. This should be attended to each time the cow is milked—three times in the twenty-four hours. If the garrot proceeds to form pus, the affected teat should be drawn regularly, and the matter coming from the teat kept separate from the rest of the milk. The endeavour should be to preserve the teat, by preventing its closing up. A cow with a light or blind teat cannot be disposed of as a sound animal, although the quantity of milk is seldom much diminished. When two quarters of the udder are affected, the result is different.

Diseases of the skin are not common in cattle that receive ordinary attention as to housing, cleaning, and feeding. *Mange* is produced either by contagion or by poverty of condition, arising from neglect. A mixture of oil and sulphur should be well rubbed into the roots of the hair. The animal should receive one pound of common salt each alternate day till the bowels are operated upon—bran mashes, roots, or green food allowed. As the disease is contagious, the patient should be separated from other cattle. *Lice* is a much more common complaint than mange; indeed, these parasites are seldom absent from cattle kept in byres or open sheds during winter and spring. Contact, direct or indirect, with animals affected, inattention to cleanliness in byres and cattle-courts, and, some believe, exposure to wet, with low diet, cause the presence of lice in cattle of all ages. Several recipes are in use: tobacco-juice, with spirit of tar, is the most common; a salve composed of mercury and lard; also soft soap and oil mixed with sulphur. Oil well rubbed into the roots of the hair, where the larvæ or lice appear, is the best treatment. The oil closes the breathing organs of the parasites, and thus speedily kills them. The skin should be well curried, and the parts to which oil has been applied may be washed with soft soap and water, followed by rubbing with dry wisps. The byre or sheds should be gone over with lime-water, to destroy any of the larvæ in the wood-work or stone walls.

Red-water occurs frequently during spring and

towards the end of autumn among cattle grazed on low damp situations, subject to hoar-frost. It also occurs during summer, when the season is dry, with heat and cold alternating. The disease is confined chiefly to young animals, or cows that have recently calved. Red-water has been attributed to sudden chills; the animal exposed to the sun's rays during the day, lies all night on cold ground, while the temperature falls below the freezing-point. The disease is connected with a deranged state of the digestive organs, principally of the liver. The first symptom is diarrhœa, with loss of rumination; this is followed by constipation; the fæces also become black, and the animal rapidly loses condition; and if in milk, the secretion almost wholly ceases. The disease should be treated with calomel. The following may be given in oatmeal gruel: Calomel, one and a half scruples; carbonate of ammonia, four drachms; sulphur, six ounces; sulphate of magnesia, six ounces. After the animal is convalescent, exposure to cold or extreme heat should be avoided.

Chronic diarrhœa is common to cows that have been improperly managed when young; it is also hereditary. The disease is generally, however, owing to recurrence of causes commonly unsuspected, till the constitutional disturbance shews itself. The animal loses condition. Diarrhœa is frequently the concomitant of other diseases, consumption being the most common. With cows turned out daily during early spring, or kept late in the season at pasture, receiving little house-feeding, the scanty fare in the fields, with the cold and wet, cause diarrhœa. The local terms of *wasting*, *consumption*, *rot*, *scouring*, &c. all indicate a state of disease, which, if not checked, ultimately causes death. In dairy districts, the complaint occasionally carries off a great number of cows. Calves are also subject to scour, arising from a derangement of the stomach. Carbonate of magnesia, two drachms, may be given to a calf: for cows and young cattle —calomel, two scruples; opium-powder, half a drachm; chalk, three ounces, mixed in gruel. It is sometimes advisable to empty the intestines by a dose of salts. Half a pound of Epsom salts may be given—this followed by calomel and opium, half a drachm of each given daily.

Quarter-ill, *black-leg*, *felon*, *shewt of blood*, &c. are local names for a disease of an inflammatory nature, to which young cattle are exceedingly disposed, unless their condition is kept up and their comfort otherwise studied. Sudden in its attack, and rapid in its progress, generally terminating fatally, all that can be successfully attempted is *prevention*. The animal is observed to be lame; the affected limb when examined is found swollen; the skin over the part, when pressed, gives a crackling noise; exudated bloody serum is collecting in the cellular tissue. The inflammation proceeds; mortification ultimately ensues; and the animal usually dies within a few hours after being observed to be unwell. Calves weaned and kept late in the season at pasture, in fields exposed to the prevailing winds or to the miasma of a marsh or damp ground, with the herbage hard and deficient in nutriment, are extremely liable to become affected, either during the period or within some months after they are removed. When the disease appears after the removal, the feeding has usually been improved in quality. A sudden change in the flow of blood causes a febrile condition, followed by congestion in one or other of the limbs—in some cases, in the brisket. An extrication of gas, followed by serum, in the cellular membrane, and, if the animal survives, extensive sloughing of the skin, take place; but sloughing is so exceptional, that few practitioners have witnessed a cure. When one animal of a herd becomes affected, the others, as well as the patient, should be bled; the intestines relieved by a dose of salts, from one quarter to one pound of Epsom or common salts. With those not affected, the supply of food should be regulated so as to prevent a rapid formation of blood. The bowels should be kept in a healthy state: to secure this, allow oil-cake from two to five pounds daily. The disease is confined to young animals; and is rarely known to attack those which have reached two years.

Catarrh, *cold*, *cough*, is often induced by exposure to cold and wet, occurring mostly in spring, when the wind is easterly. Inflammation of the mucous membrane of the air-passages which line the nostrils, causes a slight cough; the throat is usually affected, the coat staring. If the cough is short, husky, and dry, and the animal looks anxious and haggard, the inflammation has extended to the lungs; bronchitis is present, a dangerous disease, requiring the aid of the most skilful veterinary surgeon. Catarrh is not unfrequently manifested as epizootic. Fever is invariably present, but not always of the same character; sometimes of a low typhoid kind; in other cases, active. When one animal of a herd becomes affected, it should be kept apart in a warm but well-aired house; and bleeding, with aperients and counter-irritation, employed. Those not apparently affected should receive a dose of common salt, the throat being rubbed with a stimulating liniment. Cake should be allowed; if previously given, the quantity should be increased, and the animals protected from cold, and especially from wet. If they are confined to an ill-ventilated byre, a portion should be removed to another place, the ventilation improved, and cleanliness strictly carried out. The disease is so subtile, that unless the greatest care is taken, a portion may be expected to succumb. Some practitioners insert a seton in the dewlap, as a preventive of this as well as of quarter-ill.

When *inflammation of the lungs* sets in, there is quick and laborious breathing, occasionally accompanied with a low noise; cough, short and painful; the pulse is sometimes full and strong, but is frequently weak; the nostrils are dry and red, the mouth hot, the eye dull; the skin is cold to the feel, and the hair partially staring. The rumination almost wholly ceases; condition is rapidly lost; and unless the disease is checked, the animal, gradually becoming weaker, dies. Bleeding in the earlier stage, opening and keeping active the bowels, with application of counter-irritants to the sides immediately behind the armpits, are the only means at command, but they seldom prove successful in the treatment of cattle. The most insidious, and, at the same time, the most extensively fatal form of inflammation of the lungs, is

Pleuro-pneumonia.—There has been difficulty in tracing the origin of this epizootic pestilence.

It was first experienced in England in 1842, and in Ireland at least a twelvemonth previously. Introduced, it is stated, from the latter to England by a lot of half-starved cattle, the disease rapidly spread over several of the dairy counties—Cheshire, Shropshire, Staffordshire, and Middlesex suffering most. Since that period, the annual loss from the disease exceeds perhaps any estimate that has been made. Its ravages have been most extensive in ill-ventilated, crowded cow-houses. Town-dairies suffer most severely, pleuro-pneumonia sweeping off in a few months almost the entire stock—sometimes being absent for an interval of weeks, and returning with aggravated symptoms. In rural districts, the disease may be found on one farm, those in the neighbourhood being free. There are districts where the disease has never appeared. Professional opinion is divided as to its contagious or non-contagious character. Farmers, however, generally believe that it is contagious, and strong evidence has been adduced in support of this belief. The virulence is known to increase with the absence of cleanliness and with overcrowding, especially in swampy and marshy districts. The disease is seldom observed by those in attendance on the stock till it has reached the second stage. The earlier symptoms are a slight cough, breathing laboured, the coat staring, and dullness, with general depression. These tokens frequently depart for a time, returning generally in a few days with increased force. The breathing is then accelerated, the cough becomes more painful, the animal moves unwillingly, looks dull, the eye anxious, the appetite and rumination being impaired. In the third stage, rumination is suspended, respiration short and catching, the belly tucked up, the cough still more husky and painful; the anxious expression is followed by the eye becoming glassy; condition is rapidly lost; the animal breathes with difficulty, and dies from suffocation, or from general prostration.

Various remedies have been tried to combat the disease; bleeding was at first recommended as the sheet-anchor. When bleeding was practised at the second stage of the complaint, it was observed rather to hasten than to retard the crisis. Inoculation, as a means of prevention, was much lauded for a time, and its efficacy is still believed in by owners of stock in Holland, Belgium, and parts of France. In England it never found many advocates. Arsenic and other powerful medicines have been all recommended, experimented with, and found inefficient. The general opinion and practice is now, upon the first appearance of the disease, to slaughter the animals affected on the spot, and carefully to disinfect the premises. Sometimes, however, treatment may be attempted with single animals, at a distance from other stock, or with highly valuable animals for breeding purposes, where the means of complete isolation can be obtained. If the disease is observed in the first stage, blood should be taken, the throat rubbed with a blistering liniment, the bowels acted on by salt, and green food should be given. The febrile symptoms checked, tonics, sulphate of iron with manganese, should be given, a small portion of nitrate of potash added, and the animal kept in a well-ventilated place, all draughts being avoided. If the patient is a cow in milk, cure is unlikely, this disease being extremely fatal with dairy-stock, particularly those in full vascular condition. Cold, damp, and foggy weather, particularly with occasional gales, appears to hasten the development, if not the generation of the disease. As the disease is both epidemic and contagious, the employment of every precautionary measure is necessary.

Eczema, *fever in the feet*, *foot disease*, *mouth disease*, *vesicular epizootic*, *epidemic*, &c. are terms for a disease which is highly contagious, as well as epidemic. It spreads rapidly through the whole herd, and may be communicated to animals of a different species—sheep, pigs, poultry, &c. This complaint was unknown in Great Britain previous to 1839. The first symptoms are a cold shivering fit, the body trembling and parts quivering; the whole being cold, especially the extremities. There is a discharge of frothy saliva from the mouth; food is refused, and rumination is suspended. The cold is followed by reaction; the extremities become hot; the muzzle dry; the mouth, hot and sore; tongue, swollen; vesicles appear on the tongue, lips, and other parts of the mouth. The animal becomes restless, the legs sometimes shaking with violence. The hoofs suppurate; blisters form at the union of hair and hoof, and between the toes, and pus is sometimes discharged from the openings. The animal becomes very lame, walking with difficulty, and placing the heels first on the ground. The disease usually runs its course in seven to fourteen days, terminating favourably. There are cases, however, when the animal is unable to rise, and there is a general prostration of strength; and unless the animal is nursed, and care otherwise taken, death follows. The general treatment should consist of a dose of salts, one pound; sulphur, four ounces. The feet should be bathed, and if the animal is down, they should be poulticed, and the hoofs pared close. If blood exudes from the toes, the recovery will be more speedy. Dress afterwards with an astringent lotion; and if proud-flesh appears, a stronger caustic must be used. The laxative medicine should be followed by tonics—Sulphate of iron, two drachms; ginger, two drachms, given daily. Oatmeal gruel, given by a horn, if the animal will not drink—poured down the throat not less than three times daily—and green food or sliced roots offered. Every means should be used to keep up the system, as the disease is generally accompanied by great prostration. Upon the first appearance of the disease, it was regarded with great alarm—stock lost condition; and where care was not taken, death occurred. The disease is now much more mild, less frequent, and is not a cause of much anxiety.

Cattle Plague, *Steppe Murrain*, or *Rinderpest*, is the most virulent and fatal of all the diseases that the bovine species are liable to. It is of the nature of an eruptive fever, and is highly contagious. It is readily carried by individuals from unhealthy to healthy herds, and it is found that stock in the direct line of the wind, several miles distant from diseased animals, are certain to become affected by it, and form new centres for its spread. It is indigenous in the steppes of Southern Russia and in parts of Austria, whence it has at various times overspread the western countries of Europe. The number of animals which have died from this disease is almost fabulous. In 1745, it was imported into England from Holland, and continued

its ravages for twelve years, destroying hundreds of thousands of cattle. The outbreak in Britain in 1865–67 was distinctly traceable to Russia. Its ravages were frightful; in Edinburgh, for example, four-fifths of the dairy cows perished in the course of five months. In two years nearly 300,000 were attacked, and by far the greater part either died or were slaughtered. In herds numbering from 50 to 100 animals, frequently not more than one or two ultimately recovered.

Among the symptoms, the following are the most prominent: The animal is dull, and hangs its head; the eyes are leaden and watery, and from both eyes and nose there latterly comes a dirty slimy discharge. Death usually occurs about the seventh day. No remedy hitherto tried seems to have any effect even in modifying the course of the disease. The 'stamping-out plan'—that is, slaughtering at once not only the animals affected, but also all the healthy animals that have been exposed to the contagion, was first thoroughly carried out in Aberdeenshire, where eight distinct outbreaks of the plague were promptly got rid of. This example encouraged parliament to pass a measure granting increased powers to the Privy Council to regulate the traffic in cattle, and by means of 'Local Authorities' in each district of the kingdom to stamp out this insidious disease, and to remunerate (at least in part) the owners of stock so destroyed. The effects of this energetic proceeding were speedily apparent, and the plague was stayed. In 1872 a fresh outbreak took place on some farms in Yorkshire, traced to some foreign cattle imported at Hull, but here again the 'stamping-out' prevented its extension. Orders in council also insure a proper inspection by veterinary surgeons of all cattle from foreign countries on their arrival here; and by the establishment of county and district local authorities, all animals infected with any contagious disease are so treated as to prevent further infection; and now *pleuro-pneumonia* may be stamped out in the same way as rinderpest. The regulations as to all these matters may be obtained from any district constable.

FATTENING FOR MARKET.

Rules for Selecting Cattle.

In selecting cattle for *feeding*, the first point is to fix upon the breed suitable for the character of the accommodation, and for the food intended to be supplied—also, whether for winter or summer feeding. The next consideration is the age, and certain indications as to the fattening qualities of individual specimens or lots: those animals whose forms are symmetrical, having the back straight, ribs well arched, chest deep and full forward between the fore-legs, quarters long and broad, legs rather short than long, the joints being large, fatten rapidly. But the most certain indication of a quick feeder is a soft, mellow, vascular skin with a covering of silky hair. The character of the horns, when these are present, also indicates the feeding qualities. The horn differs in the sexes, castration producing a great change in its form. In all cases, the horns should be placed wide rather than close, growing outward and forward.

To judge of the age of cattle by outward signs, considerable experience is necessary. The dentition is the most certain guide; still, there are considerable variations, due in some measure to such causes as feeding and breed. Professor Simonds has found, from a long series of observations, that the following are the averages of the appearance of the incisor teeth:

Average of Early Dentition.		Average of Late Dentition.	
1 year 9 months	to	2 y. 3 m.	Two permanent incisors.
2 years 3 "	"	2 " 9 "	Four " "
2 " 9 "	"	3 " 3 "	Six " "
3 " 3 "	"	3 " 9 "	Eight " "

The dentition is completed about the fourth year; consequently a four-year-old animal will be what is called 'full-mouthed.' The incisors shew the age, becoming worn and flat with time and use. The animal gets four successive sets, changing them in the order in which they first came in. The horns also indicate age, rings appearing each spring. The first ring appears at three, sometimes, however, at two years, particularly in the female which has produced. In the market for dairy-stock, the use of the file and sand-paper is sometimes traceable on the horns of middle-aged cows.

Methods of Housing and Feeding.

Cattle are fattened for market by several methods. Besides grazing in the fields during the season of grass, they are fattened in courts or boxes, receiving regular supplies of green food—grass, tares, &c. Usually, cake and corn are given as auxiliaries.

It is in the winter-feeding of cattle that the greatest difference of opinion exists among practical men, both as to the mode of housing and the manner of feeding.

Fold-yards with sheds are the most common method of housing. When these are constructed so as to divide the cattle into small lots, and the shedding is ample and comfortable, cattle are found to make equal progress with those confined in byres or loose-boxes, provided the climate is not severe. Where the rainfall is excessive, and where the cold, either from altitude, exposure, or latitude, is considerable, cattle make greater progress confined in byres or in loose-boxes.

Stall-feeding is the common term where the animals are fastened up in stalls or tied to stakes. From the restraint preventing exercise, young cattle, one and two year olds, generally suffer from diseases of the joints after they have been kept in one position for two to four months. When the knee and hock joints become inflamed and swollen, further progress is arrested, and the animal requires to be placed in a loose box or open shed to recover. If the removal takes place upon the first appearance of joint disease, the rate of progress is little checked; but when delayed for one month or more, the animal seldom recovers so as to repay the value of the food consumed in fattening. The advantages of stall-feeding consist in the economy of house accommodation and of food, and in the equal distribution that it secures of concentrated feeding-substances.

Box-feeding has lately been much advocated. When the boxes are properly constructed, and the comfort of the animals otherwise studied, this system presents, on the whole, advantages which neither of the more common methods possesses

The cattle are placed either singly or in pairs. When single, the divisions are usually spars, to admit of the animals seeing one another. Spars being more economical than walls of stone or brick, are the more common division, even when two or more cattle are placed together. The advocates of box-feeding assert, that besides the warmth and shelter provided without the restraint of the stall, there is economy of straw used for litter; and, without question, the manure is very superior to that produced in open courts or from byres.

Board-feeding has also been advocated by Mr Mechi and others. But cattle kept on sparred boards do not advance in the same ratio as cattle kept in loose boxes or open sheds, with their comfort secured by well-littered beds—the feeding and other conditions being similar.

The methods of feeding present even greater diversities than the systems of housing. In England, the practice is rather to restrict the consumption of roots; while in Scotland, turnips are given without stint. In the former, hay is the usual fodder; in the latter, straw. Both fatten cattle at nearly the same rate of advance, which is on an average about two pounds of live weight daily.

The most recent and most highly approved system of preparing the food is to cut the fodder—a mixture of hay and straw—and to reduce the roots by a pulping-machine. The cut fodder and the pulped roots are mixed together, and afterwards given to the stock. Some feeders advocate that the mixture should be allowed to lie in a heap for some hours before it is put into the feeding-troughs. Besides the mixture of fodder and roots, the adding of dissolved linseed or cake, made into a jelly, is practised, and with the best results. The economy of roots is so considerable that the consumption is reduced to fully one-half; and the progress obtained is the maximum.

The most general practice is to house cattle early in October, and to commence feeding with the softer varieties of turnip; these, continued up till the month of January, are followed by Swedes or mangel-wurzel. Cake or corn is allowed; sometimes a mixture of the meal of barley and beans is given along with oil-cake, equal weights of each. As the condition of the animals advances, the allowance of cake, corn, &c. is increased. Commencing with three pounds, the allowance is augmented to ten pounds daily.

The quantity of roots an ox will consume depends in some measure on the age, condition, and size of the animal, but especially upon the quantity of auxiliary feeding-substances given along with the roots. An ox which, when fattened, will weigh 60 stones of 14 pounds, will, with straw as fodder, consume of white turnip, 160 to 180 pounds daily; of Swedes, 120 to 160 pounds; of mangel-wurzel, 100 to 140 pounds. When the roots are reduced to thin slices, or are pulped, and then mixed with chopped forage, the consumption of roots will diminish about 25 to 40 per cent. When the allowance of concentrated feeding-substances amounts to five pounds daily, the reduction in the weight of roots is about 10 per cent. With auxiliaries to the weight of ten pounds daily, the quantity of roots eaten is reduced by 30 to 50 per cent. when cake and cut forage are allowed.

DAIRY HUSBANDRY.

Dairy husbandry is generally practised in low-lying districts, with an argillaceous soil, producing nutritious herbage. Occasionally, dairy-farming, combining the rearing of cattle, is followed in upland and moorish districts, unsuitable for sheep or for arable husbandry, and the fattening of stock. Dairy-farms in England are most frequently to be met with in Cheshire, Gloucestershire, Wiltshire, Lancashire, Leicestershire, and the counties of Devon and Somerset; in Scotland, in the counties of Ayr, Renfrew, Lanark, Dumbarton, Stirling, Linlithgow, Wigton, and Kirkcudbright. In Ireland, the best dairy-farms are to be met with in the southern counties, the best quality of butter being shipped at Cork.

A well-arranged homestead, having every convenience to accommodate the cattle, and to store and prepare their food, is of essential importance in a dairy-farm.

An excellent arrangement for a dairy-farm steading will be found in Mr Stephens's elaborate work, *The Book of the Farm*, vol. ii. p. 289.*

Cow-houses—Cleaning.

Cows cannot be profitably maintained unless they are treated carefully, and their comfort secured as to house accommodation, feeding, and cleanliness. They should be kept during winter in roomy, well-ventilated byres; and in summer they should be protected against cold, damp, and heat. To secure this protection, the byre should be occupied part of the twenty-four hours during all seasons of the year. The cows should be kept as free as possible from all extraneous annoyance, such as flies, skin-irritation, &c. Many of the points to be attended to in the construction of stables (see No. 39, THE HORSE), are of equal importance in that of cow-houses.

Single stalls are preferable in almost every point of view to double. The cows are more easily milked, and not so troublesome or restive as when confined with a neighbour. The division between the stalls—or the *travis*, as it is termed—should be of wood; but stone is commonly used in Scotland. In the majority of byres, travises are absent, the cows being tied to a stake—a round post of wood fixed in the ground at the one end, and above to a wooden beam, which passes the whole length of the byre, with the ends built into the walls. For floors, see our remarks on stables in the number on THE HORSE. The manger should not, as is frequently the case, be on a level with the floor.

There are various ways of binding or fastening cows to the stall. The *baikie* is objectionable, as it only allows of one position being maintained. The *seal* is said to be the best. This consists of a chain or ligature provided with a hook and clasp for retaining it round the neck of the cow; the other end terminates in a ring, which is allowed to slide up and down a post placed in an inclined position at the head of the stall. The lower part of the window should be made of two shutters, the upper part glazed. Where a number of cows are kept, the *byre* or *shippen* should have a central passage, the stalls being arranged right and left

* Blackwood & Sons, Edinburgh and London.

of this, with smaller passages between the rows of stalls. In this way, the cows lie in the direction of the central passage, at right angles to the smaller passages, and tail to tail, so that the dung from the cattle of the two rows of stalls is easily removed. In some byres, there is a passage in front of the cows, affording facilities for feeding, &c. In a few instances, the byres are so arranged that the cows stand with their heads to one another, a passage between them admitting of feeding. This form is common in districts of Holland. The root-house should be at one end of the byre.

GENERAL MANAGEMENT.

Dairy-stock.—To insure the perpetuation of valuable qualities in cows intended for the dairy, it is necessary to breed from good bulls of a variety similar to the cows. Cross-bred animals are frequently good milkers, but it is not deemed advisable to continue to breed from such. As the form of the milk-vessel and the milking qualities descend from the sire rather than from the dam, it is important to select bulls of good parentage on both sides. The heifer, if properly fed, should begin to breed at two, or not beyond three years old; the cow is at her prime at from four to seven years, and falls off at from nine to twelve years, at which age it is customary to fatten her for market. In selecting cows for a large dairy for supplying milk for town-consumption, a preference is usually given to cows that have had their third or fourth calf. The period of service of the bull varies considerably; breed, mode of feeding, &c. all influence the time a bull can be kept for service. In the more highly improved breeds, such as the Short-horn, one-year-old bulls are preferred by some. Occasionally, superior animals are kept till twelve years. In ordinary breeds, such as the Ayrshire, Polled, and Highland breeds, the bulls are reserved till they reach two years, and are retained till the age of four, or seven years.

The period of gestation in the cow varies considerably; the average period is about nine months two weeks. A calf is most likely to survive and be healthy which has been carried the full time. Calves have survived that were born in the seventh month, also those that were calved in the eleventh month. Heifers come into season generally when about fifteen months old; there are instances of Short-horn heifers being impregnated at seven months. The age at which they take the bull is regulated by the breed, and in a special manner by the food. Heifers and cows come into season at different periods of the year; but spring, summer, and autumn are the more common periods. The cow remains in season about twenty hours. The periodic return is from three to four weeks, unless she is impregnated. Once impregnated, the desire ceases, if the animal is in health. After parturition, the cow, if highly fed, will come into season in three weeks; with ordinary diet, the period may be six or more weeks. Under a very low diet, or in low condition from disease, the cow does not come into season till the flow of milk is considerably diminished. In the Shetland Islands, to be in calf one season, and to be farrow next, is not an uncommon occurrence.

The period during which a cow will yield milk depends, in some measure, on the feeding. If not in calf, the flow of milk may be kept up for several months beyond the average period, which is nine to ten months. There have been instances of cows milking well the second season, and falling little short in quantity of those having had calves; but these cases are exceptional. Heifers that had never been impregnated have yielded milk in a moderate quantity, while in very exceptional instances the flow has been considerable; but, as a rule, the secretion is most abundant when the animal has produced a calf at the usual period of gestation, the calf being pure, not cross. The sex of the calf has been supposed to influence the amount of the secretion: with a bull-calf, the quantity, it is generally believed, is greatest.

The cow may be kept in milk up to within a month of the period of calving, but should be allowed to get gradually dry from six to twelve weeks previous to the expected period of parturition.

Calving.—A healthy cow will have no difficulty at parturition. She should be kept quiet, and no assistance given except in difficult cases. A shepherd, or one familiar with stock, may assist, particularly if there is a false or wrong presentation; but the more prudent course in difficult cases is to summon the veterinary surgeon. After parturition, the calf should be removed, rubbed, and partially covered with straw. Some prefer to place the calf before the cow, sprinkling salt over the calf. Most dairy-maids also throw a portion over the loins of the cow! The calf is removed after it has been gone over by the tongue of the cow, and is either placed in a house away from the byre, or it is tied up behind the cow in the byre. The suckling of the calf is gradually becoming less practised, and is now confined principally to such mountain breeds as the West Highland, or to the more highly improved breeds, the Short-horn and Hereford. Short-horn breeders sometimes provide a nurse, drying the cow after parturition. With heifers, this practice improves the size, condition, and general symmetry. With cows, the secretion of milk is frequently impaired from the state of obesity in which the animal is kept. Such cows, after parturition, should receive one pound Epsom salts, with one ounce of nitrate of potash, and two drachms of ginger, and the flow of milk should be encouraged. Cows kept for milk should receive no medicine, an occasional handful of salt excepted. This, given in warm drinks, will tend to induce thirst; to allay which, more water, with the chill taken off, and containing a portion of the water in which barley has been boiled, should be given. The allowance of food should be restricted to two handfuls of boiled barley daily, with hay or green food. No roots, meal, or cake should be allowed for the first three days; after which, if no unfavourable symptoms appear, the quantity of food should be gradually increased, and cake allowed; care being taken that the cow does not drink cold water for some time after calving.

Calves not suckled should receive warm milk twice, still better, three times in the twenty-four hours. The quantity at one time, for the first two weeks, should not exceed three pints. Afterwards, the quantity of milk should be gradually increased. In fattening calves for veal, there is little danger

from giving as much milk by the third week as the calf will take. Some feeders give eggs in addition to milk—two or more eggs daily. The shell is broken, and the egg is placed over the root of the tongue. When the allowance of milk is what the calf will drink, chalk should be added occasionally—one quarter to half a pound weight; this assists digestion. The calf intended for slaughtering should be kept dark, confined in little space, and receive no other food than milk. Whiteness of flesh indicates that the feeding has been only milk. The common practice of slaughtering calves a few days, and sometimes only hours old, should be legally suppressed. In France, where upwards of two millions of calves are annually slaughtered, calves cannot be exposed in the metropolitan markets till they are five weeks old.

Calves to be reared should have abundance of milk for the first four weeks, and that the milk of a cow newly calved. After four weeks, linseed or linseed-cake gruel should be allowed—not mixed with the milk, but given at a different time; the one diet of milk, the other of gruel. Hay or grass may be hung up within reach, and cake finely broken placed in a trough before the calf. As the animal takes to the gruel, cake, and grass, the milk should be gradually withdrawn, care being taken so to maintain condition, that the plumpness of the well-nursed calf is not lost. After the calf eats grass freely, it may, along with others, be turned out to a small paddock, but housed during the night. If a male, and not intended to be reared as a bull, it may be castrated when one month old, a west wind and a mild temperature being chosen for operating. Heifers are now seldom spayed; the operation is difficult.

Modes of Feeding.

The cow, after recovery from calving, requires an abundance of food, to keep up the secretion of milk. The feeding should be regular, from morning to night, and water must be offered at proper intervals, if the animal has not the full liberty of drinking out of a pond or running stream.

Regarding the nature of the food of cows, although soiling, or artificial feeding in the house, is at all times economical, there can be no doubt that the best milk, butter, and cheese are produced by cows fed on natural pasture. Permanent pastures are to be preferred. Those lands having a damp and saline bottom produce the most suitable food. On inclosed farms, it is the custom of many to keep their cows out both night and day from May till the end of October, so long as a full bite can be obtained; while others bring them into the house twice a day to be milked. In moorland and uninclosed districts, they are put under the charge of a herd through the day, and are brought into the byres during the night. In either case, exposure to wet and cold, or to extreme heats, should be guarded against.

Soiling, or feeding entirely in the house or court-yard, is seldom practised. Partial soiling is occasionally resorted to, by serving out a considerable quantity of rich green food to the dairy-stock in their stalls at night and during the heat of the day. This mode of feeding is more especially followed when the pastures begin to fail; the second crops of clover and first crop of tares, cabbages, and other farm-produce, are all given to the cows in the house at this period. In the best-managed dairies in Scotland, when the cows are taken in for the winter, they are never put out to the fields until spring, when the grass has risen so much as to afford a full bite. In the moorland districts, however, they are put out to the fields for some hours every day when the weather will permit. In these districts, the winter food is marsh-meadow hay, occasionally straw, with turnips, boiled chaff, and other refuse from the barn. In the best dairy-districts in England, the cows are fed principally on hay during the winter and spring months. In the vale of Gloucester, &c. the number of acres required for hay equals the number depastured, about 150 stones of hay being produced on the acre. A small portion of roots, turnip, mangold, white carrot, is allowed by most dairy-farmers. Cows in milk have the turnips sparingly supplied. When they are milked, a small piece of nitrate of potash is placed in the milk-pail; the milk as it flows from the udder dissolves the nitrate—this removes almost wholly all traces of the peculiar taste of the turnip.

Where convenient, the cows should be changed from one field to another. Eight days is the longest period they should remain in the same field. Some dairy-farmers prefer to shift the cows daily, grazing in one field during the day, the other during the night, the cows returning to the byres to be milked morning and evening. The study at all seasons when the cows are in milk should be, to provide an abundance of food, succulent, varied, and nutritious; The Scottish adage conveys a great deal of truth—'What gangs in at the *mou* (mouth) maks the guid milk *coo* (cow).'

Milking.

Cows are milked twice or thrice a day, according to circumstances. If twice, morning and night; if thrice, morning, noon, and night. They should not go too long unmilked, for, independently of the uneasiness to the poor animal, it acts injuriously on the secretion of milk.

The act of milking is one that requires skill; for if not carefully and properly done, the quantity of the milk will be diminished. To insure a continuance of the flow of milk, it should, therefore, be thoroughly drawn from the cows until not a drop more can be obtained. Cows should be soothed by mild usage, especially when young; for, to a person whom they dislike, they never give their milk freely. The teats may be washed clean before milking; and when tender, they ought to be fomented with warm water. If there are any sores, lard should be rubbed on the palm of the hand, and afterwards on the teats. The milking and management of the cow should be intrusted only to servants of character. In the majority of the counties of England, it is a common practice to employ men to milk the cows, an operation which seems better fitted for women, who are likely to do the work in a more gentle and cleanly manner. In Scotland, the office is exclusively confined to women; so capriciously do customs seem to vary.

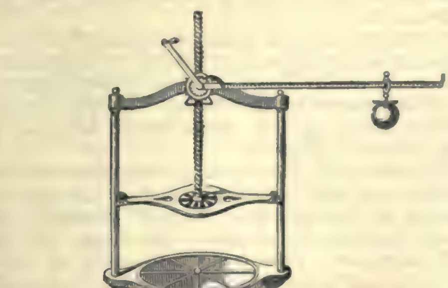
Milk.

Milk is ascertained to be composed of numerous elements, being in composition similar to blood and flesh, the proportion of water being greater.

The milk of the cow seldom contains more than 13 per cent. of solids, the average being about 12 per cent. The character of the food, the breed of cattle, the length of time since the cow has calved, with several other influencing causes, determine in part the relative proportions of the various elements. When taken from the cow, milk should be removed to the dairy or milk-house, and after being sieved, placed in shallow pans, to throw up the butyraceous matter termed cream, which, like all fatty substances, being lightest, floats on the top. It has been found by experiments that it takes 10 lbs. of milk to make 1 lb. of pressed cheese, while not less than 30 lbs. of milk are necessary to make 1 lb. of butter.

THE DAIRY.

A well-arranged dairy should consist of separate apartments, in which the various operations can be carried on—the milk-room, the cheese-room, the machine-room, and a boiler-house in which the various utensils can be washed. If completely isolated from other buildings, with the milk and cheese room facing the north, these apartments will be more easily kept cool. A covered verandah before the door, under which the washed utensils may be placed to dry, will be found useful. The milk-room should be cool, airy, dry, and free from vermin of all kinds. To prevent the intrusion of flies, the windows or ventilators ought to be covered with a fine wire-gauze. The floor should be laid with pavement, formed of sandstone, limestone, or slate; smooth glazed tiles are suitable, and where used, they should also be placed around the lower part of the walls. The benches on which the milk-pans are to be placed are made of stone or slate, and about thirty inches broad. The ceiling should be at least eight feet from the floor,



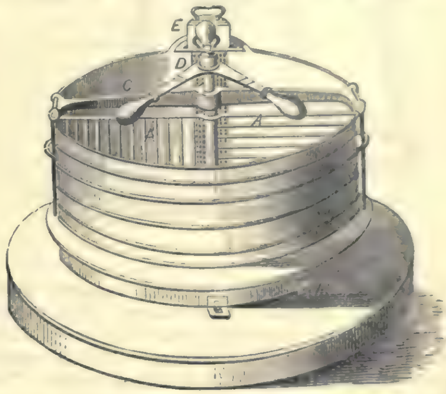
Messrs Richmond and Chandler's Cheese-press.

and finished in every respect like that of an ordinary dwelling-house. A slate roof is preferable to one of tile, as it tends to keep the temperature more equable. Cleanliness is most essential in dairy-management.

In Holland, the milk-dishes are very commonly made of brass. Zinc, and even lead-glazed earthenware vessels are objected to, on account of the action, or supposed action, of the acid of the milk on these materials producing an active poison. Glass is a good material in which to place the milk; and by using the iron vessels lined with it by a new and durable process (manufactured by the Birmingham Malleable Iron Tube Company), the only objection—its brittleness—is at once obviated.

Cheese-presses are of various kinds and weights. Granite is preferred. Presses formerly consisted of a stone weight placed upon the sinker, which was raised and depressed either by a block and tackle or a screw. The above figure represents an improved form of cheese-press, manufactured by Messrs Richmond and Chandler, Salford.

A patent cheese-making apparatus coming into use in well-managed dairies is represented in the following figure. The inventor is Mr Keevil of

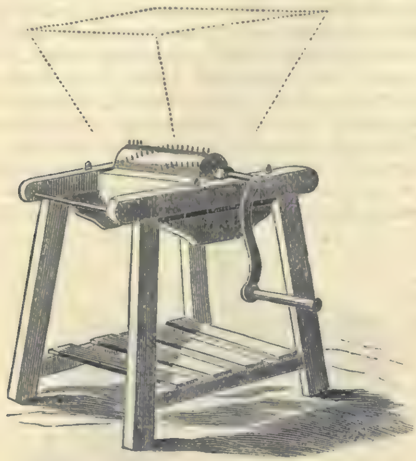


Cheese-making Apparatus.

Lacock, near Chippenham. The milk is placed in the apparatus, and curded in the usual manner. When the curd is ready to be broken up, the knives, A, A—one set of which is placed horizontally, the other vertically—are turned gently round by the small levered handle shewn in the drawing. When the curd is cut into sufficiently small pieces, the beam, C, is taken off, the knives removed, and the curd is left to settle. When the whey is ready to be drawn off, the curd is removed with a skimmer from the face of the filter, D; the plug, E, is then drawn out, and a tap, placed at the bottom of the filter, is turned on, and the whey allowed to run off. In the sketch, the plug, E, is shewn partly drawn up; when commencing to use the apparatus, it is of course pushed quite down. When the whey has run off, so as to leave the body of the curd visible, a tub cloth is placed over it, and on this a *pressing-plate*. A beam provided with a nut, in which a vertical screw works, is then fixed in a position corresponding to C. The pressure of the screw, which is turned by a handle similar to that shewn in the sketch, is transmitted to the pressing-plate through the medium of cross arms or bearers, which are placed over the pressing-plate before the beam and vertical screw are fixed. The pressure is applied gently at first, till the whey ceases running from the filter-tap. The pressing-plate and arms are then removed, the curd cut and packed in a peculiar manner, and again subjected to pressure. This is repeated till

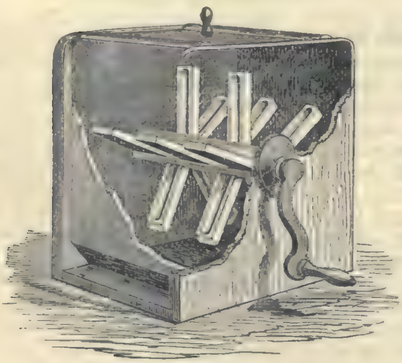
the curd is dry. An apparatus measuring 2 feet 4 inches in diameter, and 1 foot 7 inches deep, holds the curd of forty-two gallons of milk, and is capable of making cheese from ten cows once a day, or from twenty cows twice a day. The price of such an apparatus is £16.

In the figure, a form of *curd-cutter* much used in the dairies of Cheshire is represented.



Curd-cutter.

Great improvements have been recently introduced in the mechanism of *churns*. The *plunge* or *barrel* churn is rarely used except in cases where it can be worked by power. The *box*-churn with vertical dashers is now much used. The annexed figure represents a modification of the



Anthony's American Atmospheric Churn.

box-churn known as Anthony's American Atmospheric Churn. This has a high reputation.

Butter

that is made from milk as obtained from the cow, contains more caseine than butter made from the cream. The greater portion of the butter produced in England is from the cream, which is collected in about thirty-six to forty-eight hours after the milk is placed in coolers, the depth of the milk being regulated to about three to four inches. The cream, as it is gathered and allowed to stand for a time, acquires acidity, the sugar of milk undergoing a chemical change. The butter is produced by churning. The temperature of the milk when put into the churn, the form of the churn, and the speed at which it is moved, all influence the period required to separate the butter from the milk; which milk, after the butter is collected, is termed sour-milk, butter-milk, &c. The time required before the cream of the milk, or the milk drawn from the cow, should be put into the churn, differs materially during warm weather; two days may be sufficient, especially if sweet butter is desired. A longer period than two days, however, is generally observed, as the quantity of the butter is an important element.

The length of time the milk should stand before the cream is skimmed, should be regulated by the weather; during summer, thirty-six hours; but if very hot, with much electricity in the atmosphere, twenty-four hours are sufficient. In winter, forty-eight hours, or even longer, may be necessary to the collection of the whole cream on the surface. To produce superior butter, the cream should be early collected, and only once. Churning should proceed within forty-eight hours after the cream is gathered. The temperature should be regulated to about 51 degrees Fahrenheit in summer, and 55 degrees Fahrenheit in winter; the agent employed, cold or hot water. The temperature at which butter can be produced by agitating the milk, has been ascertained to range from 50 to 80 degrees Fahrenheit. Some colouring matter is usually added to the milk previous to churning. Saffron, annatto, juice of the carrot, are used. All colouring matter should be avoided, but the public opinion as to the colour of rich butter guides practice. In Holland, the butter produced in winter is white. The colour obtained from the cows depasturing on old rich pastures, is a colour lighter than the greater portion of the butter exposed for sale—salt, powdered, or fresh. Churning at a low temperature retains a portion of the colouring matter, which otherwise would pass into the butter-milk.

The best quality of butter is obtained at a temperature of 51 degrees, according to experiments performed by Mr Poole; and the greatest quantity at a temperature of 56 degrees. During the process of churning, the agitation will increase the heat about five degrees.

In some of the dairies in the neighbourhood of Edinburgh, and in all those near Glasgow, as indeed in Scotland and Ireland generally, the butter is made by churning the cream and the milk together. This is done in order to obtain the butter-milk, the demand for which is generally great. When the milk and cream are to be churned together, the milk is kept in the coolers for from twelve to twenty-four hours, and then poured into a milk-tub. It remains here until required for churning, and will, during this time, have partially coagulated.

The operation of churning, whether it be of cream alone, or cream and milk, is performed in the same manner. Milk requires more time than cream to complete the process, from two to three hours being sometimes necessary, while cream alone may be effectually churned in one-half to one hour. It is necessary that the operation should be slow in warm weather; for if done too hastily, the butter will be soft and white. In winter, the operation of churning should be done

as quickly as possible, the action being regular; and the churn should be warmed, to raise the temperature of the milk or cream. The air which is generated in the churn should be allowed to escape, or it will impede the process by the froth which it creates. After the butter is formed, it should remain in the churn to cool for one hour in summer.

After the churning is performed, the butter should be washed with cold spring-water, with a little salt added, the water being changed two or three times, to extract all the milk which may be lodging in the mass.

Butter-milk.

This is the liquid which remains after removing the butter. If milk has been employed for churning, the butter-milk is inferior to that from cream. Good butter-milk is exceedingly wholesome and nutritious. In Ireland, it is largely used at meals with potatoes; in Scotland, it is more frequently partaken of with oatmeal porridge. For this purpose, large quantities are brought to Glasgow, Edinburgh, and other towns, from the adjoining rural districts. In England, the butter-milk of farmers is usually employed in feeding pigs. In some districts, skim-milk is also given to pigs. Latterly, butter-milk has been used in conjunction with carbonate of soda in the preparation of a light and wholesome household bread. In the west of Scotland, a kind of cheese is prepared from the butter-milk.

Cheese.

Cheese may be made from cream alone, or from the whole milk; also from skim-milk and from butter-milk: the process consists in separating the serum from the other materials. This is effected by curdling the cream or milk by the infusion of an acid, the refuse being the serum or whey, which is of little value. No acidulous substance is found so suitable for curdling milk as *rennet*, which is formed of the stomach of a calf that has been fed on milk. Some persons preserve the maws or stomach-bags of calves with the curd contained in them; others employ the stomach-bags alone, putting a few handfuls of salt into and around them. They are then rolled up, and hung in a warm place to dry, and are kept for some time before they are used. The stomach is not made use of in Gloucestershire until it is a twelvemonth old; for, if used before this, it is said to swell the cheese, making it full of *eyes* or holes. The usual way of preparing the rennet in England is to add to every six skins or stomachs two gallons of brine, and two lemons, which take away any unpleasant taste, and give the rennet an agreeable flavour. A large quantity is made at a time; and it is never used until it has stood at least two months. In Cheshire the rennet is prepared every morning; a portion of the *vel* or stomach is cut off, and put into hot water; after it remains some time, the liquid is added to the milk. A portion equal in size to a half-penny will curd the milk of thirty to forty cows. Rennet so obtained does not impart any disagreeable taste to the cheese. Rennet prepared by the more common method, generally gives an unpleasant taste. Almost every dairy county has its own particular method of steeping and salting the maws and preparing the rennet.

Whey.

Whey, or the thin watery serum of milk, is of a pale-greenish hue, and forms an agreeable beverage. Some dairy-farmers in England are in the habit of extracting a little butter from it. In Scotland, whey is used in making oatmeal porridge; and a saving of nearly one-third of meal is effected when the porridge is made of whey instead of water. By boiling, float-whey, as it is called, is obtained, which, when mixed with a little sweet milk, is thought little inferior to curd. Whey is valuable in feeding swine. Sugar is prepared from whey. The production of crystallised milk-sugar is chiefly confined to Switzerland. It is sold in thick crystalline crusts; colour, yellow and yellow-brown. The production is limited, and does not compete with sugar from the cane or beet-root.

Cheshire Cheese.—It has been remarked, that although good imitations of the cheese made in the English counties have been produced elsewhere, yet cheese possessing the true Cheshire flavour is exceptional. This is attributed to the abundance of saline particles in the soil. Cheshire is almost entirely a dairy county. In making the cheese, the practice followed is to set the evening's milk apart till the following morning, when the cream is skimmed off, and two or three gallons of the skimmed-milk is put into a vessel, which is immediately placed in hot water, and rendered scalding hot. Half of the milk thus heated is poured upon the night's milk, and the other half mixed with the cream. The morning's milk is added to that of the previous evening, and the rennet and colouring being then put into the tub, the whole is well stirred, and a wooden cover put over the tub.

When the curd is formed, it is cut with the cheese-knife, making the incisions about an inch distant from each other; the whey is removed as it collects on the surface. The curd is then broken by the dairy-woman, until every part of it is made as small as possible, about forty minutes being generally spent in this process, when the curd is left about half an hour to subside, covered over with a cloth. After this, the curd is put in a favourable position in the tub to drain; after which it is cut into pieces, and pressed both with the hand and a weight, so long as the whey continues to flow.

The curd is now broken very small, and salted. As soon as the curd adheres together, a weight is put upon it, and several iron skewers are stuck through it by holes in the sides of the vat. These holes are made in order to allow any whey to escape. The curd is afterwards broken as small as possible. The pressing and skewering are again repeated. When no more whey can be extracted, the curd is turned in the vat, and rinsed in warm whey. The cheese is next put into the press, skewered with strong wires, eighteen or twenty inches long, and sharp at the points. The vat is furnished with holes on the sides to receive the skewers. After being about half an hour in the press, the cheese is turned several times, and each time supplied with a dry cloth. It remains in the press for forty-eight hours, and then the cheese is put mid-deep into salt, its top covered with salt, where it remains for three days, its position being reversed each day. When

taken out of the vat, it is put into a wooden hoop or girth of the same breadth as the thickness of the cheese, and is placed on the salting-bench, where it stands about eight days, being well salted during that time. It is then washed and dried, and rubbed with sweet butter.

The double Gloucester cheese, which is held in such high repute, is almost wholly made in the vale of Berkeley in Gloucestershire. Its excellence is said to depend much upon the quality of the land, and the great attention that is paid to the management of the dairies. It is usually made in the months of May, June, and July.

The single Gloucester is half skim-milk cheese; 'the double Gloucester or *best making* cheese, is manufactured from the pure or unskimmed milk; although it is not unusual in a large dairy to set aside sufficient milk to afford cream and butter enough for the family, and afterwards to add it to the next day's milking.'

Stilton cheese is made by putting the night's cream, without any portion of skimmed-milk, into the next morning's milk; but those who wish to make it very fine, add still more cream; and thus its richness depends upon the quantity of cream made use of. Butter is also said sometimes to be used in its manufacture. The rennet is then added without any colouring; and when the curd has formed, it is taken out without being broken, and put whole into a sieve or drainer. In the drainer it is pressed with weights until all the whey is extracted, and when dry, put into a hooped chessel. The outer coat being salted, it is then put into the press, and when sufficiently firm, it is taken out of the chessel, and bound tightly in a cloth. This cloth is changed every day until the cheese is quite dry, when it is removed; and the cheese requires no further care except occasional brushing and turning. The Stilton cheeses, although small—not weighing more than twelve pounds—require two years to bring them to full maturity.

Dunlop cheese, although nowhere so well made as in the parish in Ayrshire from which it derives its name, is now manufactured in the dairy districts of Scotland generally. The cheeses are made of various sizes—from a quarter to half a hundredweight. Sometimes the entire milk is used, but generally the cream is removed from the evening's milking.

Of late years, a very great improvement has taken place in the manufacture of cheese in Ayrshire, Lanarkshire, Wigton, and Kirkcudbright. It is a disputed point to whom this improvement is chiefly due. Mr James Caird, late of Baldoon, was certainly one of the first to draw public attention to the matter; but what with visits of Scotch farmers to England, and the introduction of English dairy-maids into Scotland, the cheese made in the important counties mentioned above is now equal to the best made in England. The money value of this improved quality is considered to be from 30 to 50 per cent. The annual competition for cheese and butter, which takes place at the Kilmarnock Fair, has also aided not a little in producing better quality of both butter and cheese.

Parmesan cheese is manufactured in that part of Italy which lies between Cremona and Lodi, comprising the richest portion of the Milanese territory. The cows are kept in the house nearly all the year round, and fed in summer with cut grass from the rich irrigated meadows of the country. Some of the cheeses are so large as to contain nearly 180 pounds; and the milk of 100 cows is required to produce one of this size. This cheese is made from the milk of the evening, which is skimmed in the morning and at noon, and the milk of the morning, which is also skimmed at noon. The milk is heated to about 120 degrees. The rennet is then added.

Swiss Cheese.—The finest cheese made in Switzerland is that of Gruyères, in the canton of Freiburg. It is rich in quality, and generally flavoured with a powdered dry herb, the *Melilotus officinalis.* The cheeses weigh from forty to sixty pounds each, and are exported in large quantities.

Dutch cheeses are sold under various names in this country—Gouda, &c. Holland exports annually about 30 millions of pounds of cheese, the greater portion coming to England.

American and Canadian Cheese.—The imports of cheese from these countries is now immense, and gradually increasing in favour. This has been greatly assisted by the establishment of large cheese factories, both in the United States and in Canada. As yet, we believe there is only one cheese factory, which has been lately established in Derbyshire, on this principle in Great Britain. Of the ultimate adoption of cheese factories in this country there cannot be a doubt. It is almost impossible to obtain hired servants to manage a dairy successfully, and it is invariably found that the farmer's wife or daughter must perform the duties of head dairymaid. Mr MacAdam, in his excellent treatise on *Domestic Dairying*, makes the following remarks: 'At present there is heard from many quarters a loud and earnest appeal for sufficient rest and leisure, and fewer hours of labour, and no class has better cause to turn this appeal into a demand than those employed in cheese-making. It is no uncommon thing to find them engaged from five o'clock in the morning till after eight at night, in milking, making and turning cheese, or cleaning the dairy and utensils; and this Egyptian bondage is seldom lightened by the repose and sanctity of the Sabbath, for the thoughtlessness or prejudice of landlords and farmers, or a false motive of economy, often compels them to continue their drudgery on that day. Surely such a state of affairs is worse than a want of profit, and far more reprehensible than a lack of success. Must these have no leisure, no recreation, no culture, nothing save the protracted hours of labour, and a stinted allowance of rest? Must all their energies of mind and body be directed to the accomplishment of such tasks as selfishness or apathy is pleased to impose, and which circumstances compel them to perform?'

When Mr MacAdam penned the above, he was an advocate for 'domestic dairying.' He and his sons are now managing several American cheese factories, and he advocates their adoption in England with still greater prospects of success.

Black-faced—Leicester—South-down.

THE SHEEP—GOAT—ALPACA.

OF the *Ruminant* order of the Mammalia, one of the most important is the sheep, the flesh and wool of which have been of great use to man from the earliest ages. In our own country, within the last half-century, the different breeds have been improved by the growing intelligence, skill, and industry of farmers; and their management has been brought to a degree of perfection perhaps nowhere else attained.

BREEDS OR VARIETIES OF THE SHEEP.

The numerous varieties of sheep that now exist in different parts of the globe, have all been reduced by Cuvier into four distinct species: 1. *Ovis Ammon*—the Argali. This species is remarkable for its soft reddish hair, a short tail, and a mane under its neck. It inhabits the rocky districts of Barbary and the more elevated parts of Egypt. 2. *Ovis tragelaphus*—the bearded sheep of Africa. 3. *Ovis musmon*—the Musmon of Southern Europe. 4. *Ovis montana*—the Mouflon of America; but this species, which inhabits the Rocky Mountains of North America, is now believed to be identical with the Argali, which frequents the mountains of Central Asia, and the higher plains of Siberia northward to Kamtchatka. This leaves only three distinct species of wild sheep as yet discovered.

It is still a point in dispute from which of these races our domestic sheep have been derived; nor is the question of great practical importance, though its solution is very desirable in a physiological point of view. Whether the wild races may be regarded as of one species, as some naturalists contend, or of different species, according to others, the best judges are next to unanimous that the domestic races of this country are of one species; and what are called different breeds are nothing more than varieties, the result of different culture, food, and climate. The influence of these conditions in diversifying the character and condition of sheep, will be adverted to under their proper heads. The following may be regarded as the principal breeds reared in this country:

1. *The Shetland sheep*, inhabiting those islands from which they derive their name, and extending to the Faröe Islands and the Hebrides. In general, they have no horns. The finest fabrics are made of their wool, which resembles a fine fur. This wool is mixed with a species of coarse hair, which forms a covering for the animal when the fleece proper falls off. A similar variety is known to inhabit the most northerly parts of Europe, from which it is supposed the fine-woolled sheep of our northern islands and Highlands have been derived. They are hardy in constitution, and well adapted to the soil and scanty pastures on which they are reared, but would ill repay their cultivation in Lowland districts.

2. *The Dun-woolled breed*, the colour of which is not confined to the wool, but extends to the face and legs. They seem at one time to have been cultivated very extensively, and remnants of them still exist in Scotland, Wales, and the Isle of Man.

3. *The Black-faced Heath breed*, which, being the most hardy and active of all our sheep, are the proper inhabitants of every country abounding in elevated heathy mountains. They have spiral horns, their legs and faces are black, with a short, firm, and compact body; their wool is coarse, weighing from three to four pounds per fleece; but the improved breed, which is of mixed black and white in the face and legs, yields a finer and a whiter wool. They fatten readily on good pastures, and yield the most delicious mutton; the wedder flocks, when three years old, are generally fattened on turnips in arable districts, and weigh from sixteen pounds to twenty pounds per quarter. They exist in large numbers in the more elevated mountains of Yorkshire, Cumberland, Westmoreland, Argyleshire, and in all the higher districts of Scotland where heather is abundant. Recent severe winters have led to their re-introduction in high grounds where they had for a time been supplanted by the Cheviot and other breeds.

4. *The Moorland sheep of Devonshire*—sometimes termed the Exmoor and Dartmoor—have horns, with legs and faces white, wool long, with a hardy constitution, and are said to be well adapted to the wet lands which they occupy. Their wool weighs about four pounds the fleece; but they are rather small, and in some respects ill formed.

5. *The Cheviot breed*, deriving their name from the Cheviot Hills, are longer and heavier than the Black-faced. Their wool is fine and close; a medium fleece weighs about three pounds and a half to four pounds; a carcase, when fat, weighs from sixteen to eighteen pounds and upwards per quarter. Their faces are white; their legs are long, clean, and small-boned, and clad with wool to the hough. Their only defect of form is a want of depth in the chest; yet, with this exception, their size, general shape, hardy constitution, and fine wool, are a combination of qualities in which, as a breed for mountain pasturage, they are yet unrivalled in this country, though they require a larger proportion of grass to heather than the Black-faced breed.

6. *The Horned varieties of fine-woolled sheep of Norfolk, Wiltshire, and Dorset.*—The members of this breed have short wool, in which they differ from the Black-faced sheep and the Moorland sheep of Devonshire, and they differ from the Cheviot breed in having large spiral horns. They are not much lighter than the Cheviots, but they are ill formed, thin, flat in the ribs, and slow feeders; a medium fleece weighs about two pounds. It is believed that the South-down will eventually displace them. The Wiltshire sheep are heavier than those of Norfolk, being the largest of our fine-woolled sheep. The Dorset sheep have horns, white faces and legs; their three-year-old wethers weigh from sixteen to twenty pounds per quarter; their wool is less fine, but heavier than that of the Wiltshire, weighing from three to four pounds the fleece. One of the peculiar advantages of this breed is, that the ewes admit the ram at so early a period that they generally have lambs in the months of September and October—a stock which finds a ready market in large towns for winter consumption.

7. *The Ryeland breed*, deriving their name from a southern district in Hertfordshire, which at one time was regarded as incapable of growing anything but rye. The members of this variety are white-faced, and without horns; their general form is tolerable; they fall short of the improved breeds, in being more flat in the ribs, and less level in the back; their wool is fine, weighing from one and a half to two pounds; their mutton is delicate; they arrive soon at maturity, fatten easily, and weigh from twelve to sixteen pounds per quarter. This breed has been crossed by the Spanish Merino. The offspring of this cross were at one time in high fame in England, under the name of the Anglo-Merino; but though their wool is said to have been of a fine quality, the breed has for long declined in popular favour.

8. *The South-down breed.*—The sheep of this breed have no horns; their legs and faces are gray. They have fine wool, very closely set, and the fleeces of ordinary breeding ewes weigh from three to three and a half pounds per fleece; they are slightly deficient in depth and breadth of the chest, but their mutton is excellent, and highly flavoured; they are kindly feeders, and when fat, their average weight may be stated at from fifteen to eighteen pounds per quarter. They have from time immemorial been reared upon the chalky soils of Sussex, but are now widely extended, and thrive excellently, not only on the chalk-downs and light soils of England, but on sheltered grounds in Scotland.

9. *Oxford, Shropshire, and Hampshire Downs.*—These breeds attain a much larger size than the original South-downs, and also carry heavier fleeces. It is supposed that this has been attained by a cross of the South-downs with Lincolnshire or Cotswold blood; be that as it may, they are now acknowledged as separate breeds of great value, combining the finest mutton with a heavy and valuable fleece; but certainly the Shropshire and Hampshire Downs are deficient in form. The cultivation of the Oxford Downs, in particular, is rapidly spreading, and likely to extend in all low-lying districts where pure flocks are raised simply for the butcher-market.

10. *The Merino breed*, which is supposed to have been originally from Africa. Marcus Columella saw a variety from that country at some of the games exhibited at Rome. He procured some of them for his own farm, crossed them with the breeds of Tarentum, and sent the offspring of this cross to Spain. In Spain, they soon rose to such perfection and celebrity, that they attracted the attention of breeders of stock in other nations, and this breed may now be found in every part of the globe. They were imported into England for the first time in 1788. The Ryeland and other fine-woolled breeds of England were crossed by Merino rams in 1792. The Merino breed of rams were cultivated with great care by George III. The sales of His Majesty's stock, which commenced in the year 1804, attracted such general attention in England, that a society was formed for promoting the breed in 1811; but the high expectations which were formed of the result of this cross with native sheep were far from being realised. The quality of the wool of the native sheep was improved, but the increased value of the fleece was an inadequate compensation for defects in the character of the animals themselves, which proved less hardy than the parent stock, slow feeders, very defective in form, and the mutton very inferior.

The Merinos are now extinct in Great Britain; but the immense flocks in Australia and New Zealand, alone calculated to exceed upwards of fifty millions, with upwards of nine millions at the Cape of Good Hope, to say nothing of South America, amply supply the looms of Great Britain with an ever increasing quantity of the finest wool for broad-cloth; and now even the manufactories on the Tweed at Galashiels are mostly engaged in spinning foreign wools into tweeds.

Merino sheep are treated in Spain, France, and Germany with a greater regard to the wool than to the weight and value of the animal; but the farmers in England find it more profitable to raise weight and value of mutton, combined with fleeces of combing or lustre wool, which now sells at a higher price per pound than even Merino wool. In Spain, the fleece of the ram weighs eight pounds, and that of the ewe five pounds; but this wool has such a large quantity of *yolk*, which absorbs every kind of impurity with which it comes in contact, that it loses three-fifths of its weight by being properly washed.

11. *Cotswolds.*—This breed has been long raised on the Cotswold Hills in Gloucestershire, and is abundant in the fertile valleys of South Wales. It possesses long open wool, and is perhaps the largest sheep in the kingdom. It is valued for its mutton, the lean meat being large in proportion to the fat. It is used to some extent in crossing ewes of smaller breeds, for raising feeding-stock or lambs for the butcher, but it is not equal to the Leicester for early maturity.

12. *The Devonshire Notts, Romney Marsh, Old Lincolnshire, Teeswater, and Old Leicester sheep.* There are two varieties of the Devonshire Notts; one is called the Dun-faced Notts, from the colour of the face; this is a coarse animal, with flat ribs and crooked back, but it yields a fleece weighing ten pounds, and when fat, weighs twenty-two pounds per quarter when only thirty months old. The second variety is called the Bampton Notts; it resembles the former in many respects, but is easier fed, yields less wool, and has the face and legs white.

The Romney Marsh breeds are very large animals, with white faces and legs, and yield a heavy fleece, the quality good of its kind. Their general structure is defective, the chest being narrow, and the extremities coarse. The result of their being crossed by the New Leicester is still a point in dispute—one party alleging that, though the quantity of wool has been lessened, and the size of the animal diminished by the cross, the tendency to fatten and the general form have been much improved. On the other hand, some well-informed breeders contend that, besides the loss of the quantity and quality of the wool, the constitution of the animal is rendered less fitted to the cold and marshy pastures on which it feeds.

The Old Lincolnshire breed are large, coarse, ill-shaped, slow feeders, and yield indifferent mutton, but a fleece of very heavy long wool. The Teeswater breed were originally derived from the preceding, and pastured on the rich lands in the valley of the Tees, from which they derive their name; but Professor Low remarks, that 'it is entirely changed by crossing with the Dishly breed, and that the old unimproved race of the Tees is now scarcely to be found.' They are very large, and attain a greater weight than almost any other breed—the two-year-old wethers weighing from twenty-five to thirty pounds per quarter, and yielding a long and heavy fleece.

The Old Leicester is a variety of the coarse long-woolled breeds. On rich pastures, they feed to a great weight; but being regarded as slow feeders, their general character has either been changed by crossing, or altogether abandoned for more improved varieties.

13. *The New or Border Leicester.*—Mr Bakewell of Dishly, in the county of Leicester, has the honour of forming this most important breed of sheep. He turned his attention to improving the form of feeding animals about the year 1755. The exact method he followed in forming his breed of sheep is not accurately known, as he is said to have observed a prudent reserve on the subject. But we now know that there is but one way of correcting the defective form of an animal—namely, by breeding for a course of years from animals of the most perfect form, till the defects are removed, and the properties sought for obtained. Though the Border Leicesters have been bred from the New or English Leicesters, their forms and chief characteristics are now widely different, and they are frequently classed as a distinct breed. Forty years ago, the ewes of some of the present flocks of Border Leicesters in Scotland were then composed of English blood, and rams from Mr Buckley of Normantonhill, Leicesters, and others were regularly purchased to maintain the desired purity of blood. At that time, purchasers of rams for crossing began to give larger prices for sheep of greater size and bone than those lately imported from the south. There can be little doubt this increased size and activity were merely produced by the more extended fields and cooler climate of Scotland; while the stock was still fed on pasturage rich enough to keep them in high condition. The great properties for the farmer of the Border Leicesters, as they are now called, are their early maturity and disposition to fatten. They are also of a most productive nature, three-fourths of a flock have frequently twins, and triplets are common. They have long open and spiral wool; ordinary fleeces weigh about eight pounds; but ram fleeces often reach double that weight. At one time, Leicester wool was much cheaper than the fine close wool of the South-down and the Cheviot; but now, as combing and lustre wool, it fetches the highest price in the market. Leicesters are now reared with great success in almost every part of England, and in the colonies of Australia, where they and the South-downs were early imported.

CHOICE OF BREEDS.

If the farmer has rendered himself master of the constitution and character of the different breeds of domestic sheep already given, and with the general and peculiar character of the climate, soil, and pasturage of the locality on which he is to settle, the selection of the breed that will, upon the whole, yield him the highest profit, will not be a matter of very difficult calculation. But should an error be committed on this head in the first trial, very slight experience would enable a practical farmer to correct it, unless he belong to that class of persons—unfortunately too numerous—to whom the lessons of history and experience convey neither knowledge nor correction.

The breeds best adapted to the soil and climate of the different districts of Great Britain, are arranged by Professor Low in the following manner: *1st,* The sheep of the mountains, lower moors, and downs; and *2d,* The sheep of the plains. The sheep of the first class have sometimes horns, and sometimes want them. The finest of them have no horns—namely, the Cheviot and South-down. One of them, the Black-faced heath breed, has coarse wool; another of them, the Moorland sheep of Devonshire, has long but not coarse wool; and all the others have short and fine wool.

Of the Moorland and Down breeds, as they may be called, the hardiest is the Black-faced heath breed; and this property points it out as the most suitable for a high and rugged country, where artificial food cannot be procured. The breed next to this in hardy properties, but surpassing it in the weight of the individuals, is the Cheviot. Where the pasture contains a sufficiency

of grasses, this breed deserves the preference over any other known to us for a mountainous country. The next breed deserving of cultivation is the South-down. This breed is suited to the chalky and sandy downs of the south of England. It is in this respect a very valuable breed, but it is unsuited to the more rough and elevated pastures to which the Black-faced and Cheviot are naturally adapted.

The Moorland and Down breeds appear to be the most deserving of cultivation in this country. Of the larger breeds of the plains, the New Leicester is the best adapted to general cultivation, and wherever an improved system of tillage is established, this admirable breed may be introduced. The Leicester, the Cheviot, and the Black-faced have long been regarded as the breeds best adapted for the different districts of Scotland. That these three breeds have nearly stood in the same numerical ratio to one another for some years, is a good proof that each has been placed in the locality best fitted by nature for promoting its health and productiveness. The Leicester is admirably adapted to the rich alluvial soils of our cultivated plains; the Cheviot breed is peculiarly fitted for the grassy mountains chiefly formed of the transition series of rocks; then our most elevated mountain-ranges are formed mainly of primitive rocks, and covered with coarse herbage and heath, on which none but the Black-faced, the most active and hardy of our breeds, could survive.

The above arrangements have generally been acquiesced in as the best possible by the farmers of Scotland. But the claims of South-downs for the middle range of the Highland pastures in Scotland have been urged in the following terms, by an agriculturist of long experience and high standing in his profession—namely, Mr Watson of Keillor: 'Having, during the last twenty-five years, been in the management or possession of a considerable breeding-flock of South-down ewes, varying at different times from 500 to 1000 in number, and during that period having had good opportunities of drawing close comparisons betwixt that and the other breeds of mountain sheep—namely, the Cheviot and Black-faced—I have come to the conclusion—and am acting upon it in my own practice—that from a pasture ranging from 500 to 1200 feet above the level of the sea, having a moderate portion of green-sward, the rest whin and heather, there can be no more profitable stock of sheep kept than a flock of South-downs of the best sort. My chief reasons for having preferred this breed are—that the South-down sheep, although naturally spirited and active, are easily controlled by a good shepherd; can go over more ground for their food than any other kind of sheep, without stopping their growth; and when tried by severe storms in winter, will brave it better than even the Black-faced Highland sheep; and although reduced very low in spring, sooner pick up condition than the other short-woolled sheep. As a proof of the South-downs' tendency to fatten, when put to good keep, I may mention a fact, that while I have seldom been able to produce a fat Cheviot ewe the same season that she has reared a lamb, I never fail to make good fat of the cast South-downs off grass. Their wool is so closely matted on their backs, and about the head and neck, as to be almost impervious to rain or snow; hence, so soon as the storm ceases, they appear dry and comfortable, their coat not the least disordered, and altogether free from that *drouked*—Anglicè, drenched—appearance which longer-woolled sheep exhibit even for days after a winter storm.

'In all my experience, the South-down sheep have kept remarkably healthy. I have never seen an instance of rot in my flock; while during the last twenty years, I have been forced to clear off a lot of Cheviot and also of Black-faced ewes from that incurable disease. This, however, may have been owing more to the unsoundness of the pasture from which I got them, than from any peculiarity of the animals themselves. My average loss in the South-down lot has invariably been much under that of any other sheep I have bred. They are hardy, and easily managed at lambing-time; affectionate mothers, and, on moderate keep, give a great quantity of milk; and if there is any inducement for early lambs, they will go with the ram almost as soon as the lamb is weaned. When crossed with a well-bred Leicester ram, and brought into good keep, they produce perhaps the most profitable lamb that is bred, taking wool and carcase into account. I have for the last ten years put all the ewes I could spare from pure breeding to this sort of crossing, lambing the ewes on turnips in spring, then turning them, as soon as the season would permit, to the hill-pasture—the Sidlaws—till weaning-time, when the lambs are brought to the in-field pastures, and put to turnips for the winter, on which food they are kept for about 2d. per week each, and kept on the earliest grass in spring; so that in a month or six weeks after they are clipped, they are fit for the butcher, who values this cross almost as high as the pure bred South-down. The wool is of the finest quality for combing, and fetches the highest price of any British-grown wool—generally from 2s. to 2s. 2d. per pound; and the clip in a good season will average about six pounds. At sixteen months old I have never realised less than 40s. each, wool and mutton. In Smithfield, this cross is much sought after.

'On lands where folding is found necessary, the South-down submits to this treatment better than any other breed of sheep; such, indeed, in all cases where I have put them to the test, is their spirit and hardiness, that nothing short of ill-treatment seems to injure them. Combining these facts, I can have no hesitation in recommending a South-down flock of sheep in preference to every other, on such situations as I have now described—namely, too high to be occupied during the whole season by a flock of Leicesters, and under that level above which only the native Black-faced breed can be expected to thrive.'

Notwithstanding Mr Watson's experience, the breeding of South-downs in Scotland has not increased, and the attempts which have been made to supplant either Black-faced or Cheviots have not been successful. At present, there are very few extensive flocks of South-downs in Scotland, though there are numerous small flocks in the parks of gentlemen who are particular about their mutton. As Professor Low has remarked, 'the South-down breed is best suited to the chalky and sandy downs of the south of England. It is in this respect a very valuable breed; but it is unsuited to the more rough and elevated pastures to which the Black-faced and Cheviot are adapted.' It may be added, that an ample space of dry

ground, with a somewhat scanty herbage, are the situations in which they thrive best.

IMPROVEMENT OF BREEDS.

The first point of essential importance to be attended to by the sheep-farmer is the selection of a breed whose size and constitutional qualities best accord with the climate and the pastures on which they are to feed. An error of any magnitude in these respects would be attended with fatal effects both to the health and productiveness of the flock.

It is true that sheep can exist in almost every country, and may be said to reach nearly from the equator to the poles. They are found approaching the eternal snows and icy barriers of the arctic regions; they are found at great elevations in the Cordilleras of South America, and in the still more elevated Himalaya Mountains of Asia. Yet though sheep can be reared within an immense range of latitude and temperature, it is equally true that the climate and soil fix the limits within which our domestic breeds can be cultivated with advantage. Nature has perhaps forbidden that the sheep should, in any circumstances, yield the greatest weight of the best mutton and a fleece of the greatest value. The farmer will be able easily to determine, from the country, climate, and various other considerations, to which of these he should direct his chief attention. In England, the farmer finds it more profitable to promote the weight and quality of the mutton than the wool; while the farmer in Spain, Germany, and Australia, finds it his interest to attend more to the wool than the mutton.

We have now to consider the sheep as to its most important characters when brought to market.

1. The *size* of the sheep is determined by the climate, the pasture, and the steepness or levelness of the lands on which it is fed.

2. The *form* of the sheep depends on its anatomical structure. That eminent surgeon, Mr Cline, in his communications to the Board of Agriculture, states, 'that the lungs of an animal are the first objects to be attended to, for on their size and soundness the health and strength of an animal principally depend; that the external indications of the size of the lungs are the form and size of the chest, and its breadth in particular; that the head should be small, as by this the birth is facilitated, and affords other advantages in feeding, and as it generally indicates that the animal is of a good breed; that the length of the neck should be in proportion to the size of the animal, that it may collect its food with ease; and that the muscles and tendons should be large, by which the animal is enabled to travel with greater facility; and the bones should be small and clean.'

We may here add a description of the best proportions of a Cheviot ram, by the late Mr Culley of Northumberland: 'His head should be fine and small; his nostrils wide and expanded; his eyes prominent, and rather bold and daring; ears thin; his collar full from the breast and shoulders, but tapering gradually all the way to where the neck and head join, which should be very fine and graceful, being perfectly free from any coarse leather hanging down; the shoulders broad and full, which must at the same time join so easy to the collar forward, and chine backward, as to leave not the least hollow in either place; the mutton upon his arm or fore-thigh must come quite to the knee; his legs upright, with a clean fine bone, being equally clear from superfluous skin and coarse hairy wool, from the knee and hough downwards; the breast broad and well forward, which will keep his fore-legs at a proper wideness; his girth or chest full and deep, and instead of a hollow behind the shoulders, that part, by some called the fore-flank, should be quite full; the back and loins broad, flat, and straight, from which the ribs must rise with a fine circular arch; his belly straight, the quarters long and full, with the mutton quite down to the hough, which should neither stand in nor out; his twist or junction of the inside of the thighs deep, wide, and full, which, with the broad breast, will keep his four legs open and upright; the whole body covered with a thin pelt; and that with fine bright soft wool. The nearer any breed of sheep comes up to the above description, the nearer they approach towards excellence of form; and there is little doubt but if the same attention and pains were taken to improve any particular breed that has been taken with a certain variety of the Lincolnshire, the same advantages would be obtained.'

3. *Early maturity* is a property of great importance to the farmer who breeds and feeds all his own sheep for the shambles; they not only make a quicker return for their food, but yield a higher profit to the breeder than slow-feeding animals. This valuable property of early maturity can be induced by breeding, food, and treatment. The New Leicester variety possesses this property in a higher degree than any other of our domestic breeds, and they also yield a greater quantity of mutton on the same quantity of food.

4. *Constitutional hardiness*, in a rigorous climate, and in bleak and elevated mountains, in which artificial food cannot be obtained, is an indispensable quality. But a farmer will seldom make a wrong selection in circumstances so obvious.

5. *Productiveness* is a property which characterises some varieties of sheep and other animals; it may be increased by careful selection in breeding, and by food and treatment. Pets have almost invariably twin lambs. The draft ewes from the mountains of Scotland have generally twins when taken to a milder climate, and kept on superior food.

6. *Disposition to fatten* is a property of very great importance to feeders, as their sheep can be made fit for the market both in a shorter period and with a less quantity of food. None of our domestic breeds possess this quality in greater perfection than the New or Border Leicester; but these are chiefly reared for males to cross with the ewes of the native mountain breeds, and such half-bred stock are found to combine early maturity with superior mutton. For the taste of most people, the flesh of the pure-bred Leicester is too fat, and it generally sells at from a penny to two-pence per pound less money than can be obtained for crosses, or pure-bred mountain or Down sheep.

7. *Lightness of offal.*—It is obvious that to whatever extent the weight of the offal, or uneatable portion of the carcase, can be diminished, the value of the animal is increased. The perfection

of an animal is, when the dead-weight of all the eatable parts approaches the nearest to the weight of the animal when alive.

Principles of Breeding.

The fundamental and essential principle of improving any of our domestic animals by breeding, consists in a skilful selection of those males and females the union of whose qualities will induce the properties desired. It was upon this principle that Bakewell formed his celebrated breed of sheep, and it is the only principle upon which any breed can be raised to the highest perfection of which it admits. *Breeding in and in*, as it is called, has given rise to a long controversy, which our increasing knowledge of physiology, and a wider induction of facts, carefully observed and accurately recorded, will speedily bring to a close. The facts now collected from a wide surface, and attested by men skilled in the sciences of physiology and anatomy, as well as by practical breeders of live-stock, establish the important fact, that breeding by too near affinities, the offspring degenerates. It is a law of nature, and applies to men and animals, and even plants. The accurate experiments of Mr Knight establish the fact, that in the vegetable as well as in the animal kingdom, the offspring of male and female plants, when not related, possess always more strength and vigour than those of near affinities. Sir John S. Sebright tried many experiments by breeding in and in with dogs, fowls, and pigeons, and found that the offspring uniformly degenerated. Sir John Sinclair relates an experiment with pigs, which he carried so far that the females almost ceased to breed; and if they did breed, the offspring was so small and delicate, that they died as soon as they were born. To breed, therefore, from the same race, but of different families, is now established as the only system that will secure the highest results in the different breeds.

Crossing is a means of improving a breed that requires many concurring circumstances to insure success. The climate and the food must accord with the size and constitution of the animal to be produced. To increase the size of sheep, without augmenting or improving their food, would be a ruinous enterprise, and in the face of all principle. The attempt to increase size by crossing with heavier rams from another country, requires also great care that the food and climate be adapted to the condition and character of the expected race; for it is in proportion as size is gained by crossing, that delicacy of constitution and liability to disease are increased. The constitutional qualities of a race of sheep will not accommodate themselves to the soil or climate of a country differing much in pasturage and temperature from that on which it has been long a native, without time, great care, skill, and attention. Were we to cross our mountain Cheviot ewes with Leicester rams, the offspring would labour under two fatal disadvantages—a constitution too delicate for the climate, and a size above the pasture. An attempt was made in Scotland some years ago to raise the quality of the wool of our mountain-sheep by crossing them with Cheviot rams, and the result, so far as then developed, was a complete failure. It is therefore dangerous to directly transplant the pure Cheviot breed to high-lying districts, the system adopted being that of crossing Black-faced ewes with a Cheviot ram; by this method, a hardy Cheviot stock is at length obtained, though after many generations the wool is often found somewhat inferior.

It is now generally admitted that the male has a higher influence on the character of the offspring than the female. This law is in beautiful accordance with that beneficent design so visible in the arrangements of nature, as it enables man to bring the domestic animals to their most profitable condition in a far shorter period than if the law had been reversed. There is another fact apparently well established, that the male, by one connection, has a higher influence on the second generation than the actual father. This shews that no important change in the character of any breed can be effected, unless the crossing is continued until the fourth or fifth generation.

Age of the Parents; its Effects on the Sex of the Offspring.—Some very interesting experiments were begun some years ago, the result of which, so far as they go, tend to establish, as a general law of nature, that the offspring of a young ram and ewe, of from four to five years old, will in general be feminine, while that of an old ram and young ewe will in general be masculine. Could this law be practically acted upon, it would be of immense advantage to breeders of stock in every country, but particularly to breeders of stock in such a country as Australia, in which the rapid increase of the number of stock is an object of so great importance. There is an able paper on this curious subject in the first number of the *Quarterly Journal of Agriculture*, containing the results of the experiments made in France, from which the following facts and views are extracted: 'M. Charles Giron de Buzarcingues proposed at a meeting of the Agricultural Society of Severac, on the 3d of July 1826, to divide a flock of sheep into two equal parts, so that a greater number of males or females, at the choice of the proprietor, should be produced from each of them. Two of the members of the society offered their flocks to become subjects of his experiments; and the results have now been communicated, which are in accordance with the author's expectations. The first experiment was conducted in the following manner: He recommended very young rams to be put to the flock of ewes from which the proprietor wished the greater number of females in their offspring, and also, that during the season when the rams were with the ewes, they should have more abundant pasture than the others; while to the flock from which the proprietor wished to obtain male lambs chiefly, he recommended him to put strong and vigorous rams four or five years old.'

The author of the paper says: 'The general law, as far as we are able to detect it, seems to be, that when animals are in good condition, plentifully supplied with food, and kept from breeding as fast as they might do, they are most likely to produce females; or, in other words, when a race of animals is in circumstances favourable for its increase, nature produces the greatest number of that sex which, in animals that do not pair, is most efficient for increasing the number of the race. But if they are in a bad climate, or on stinted pasture, or if they have already given birth to a numerous offspring, then nature, setting limits to the increase of the race, produces more

males than females. Yet, perhaps, it may be premature to attempt to deduce any law from experiments which have not yet been sufficiently extended. The writer of this has uniformly observed, that in every favourable season, when his stock was in high condition, he had a much larger number of female lambs than of males; and in one of the most favourable seasons that has occurred during his own personal experience, the female lambs exceeded the males to the number of ninety, in a flock of six hundred ewes. The ewes had no artificial food at any season of the year; they lived entirely on the natural grasses of our mountain pastures. They got bog and lea hay in snow storms, but nothing else.

GENERAL MANAGEMENT.

The management of sheep must be varied according to the nature and character of the breed, the soil and climate, character of the pastures, natural or artificial, the position of the farm in reference to markets, and whether all the sheep upon the farm can be prepared for the butcher, or must all be sold lean, as is the case with those farmers whose flocks subsist entirely on the natural grasses of our mountain pastures; and whether early lambs would be profitable or otherwise. These and many other circumstances must regulate the proper time for admitting the rams to the ewes, changing the lambing-season, and the proper times for washing, shearing, dipping, smearing, &c. Different names are applied to sheep at different periods of their age. A young sheep remains a *lamb* from birth till the first smearing-time. From this till the first clipping it is called a *hog*. From the first to the second clipping it is termed a *gimmer*. It is now called a *young ewe*, till it bears its first lamb. When male sheep are cut, they are denominated *wedders;* and, according to their age, are called wedder-hogs, &c. At three years old, the wedder is in its prime for mutton.

Lambing.

The period at which sheep begin to breed is in the autumn of the second year after birth, when both rams and ewes are at their maturity. In the British Islands, the company of the ram is largely permitted at the beginning of October. The ewe goes with young about 152 days; consequently the lambing-season is at the beginning of March. It is of high importance that sheep, during gestation, should be managed with peculiar gentleness and care, the rash use of the dog being attended with the most pernicious consequences. The ewes should be well but not overfed, as the ewes being in too high condition greatly increases the risk in lambing. Though parturition, being a natural process, cannot be regarded as a disease, still, in the sheep, as well as in many of our domestic animals, it is attended with some risk; and in certain states of the atmosphere, with ewes in too high condition, there is often considerable loss from inflammation.

'As the period of parturition approaches,' observes an intelligent writer in the *Penny Cyclopædia*, 'the attention of the shepherd should increase. There should be no *dogging* then, but the ewes should be driven to some sheltered inclosure, and there left as much as possible undisturbed.

'The period of lambing having actually commenced, the shepherd must be on the alert, yet not unnecessarily worrying or disturbing the ewes. The process of nature should be permitted quietly to take its course, unless the sufferings of the mother are unusually great, or the progress of the labour has been arrested during several hours, or until eighteen or twenty hours have elapsed since the labour commenced. His own experience, or the tuition of his elders, will teach him the course which he must pursue.

'If any of the newly dropped lambs are weak, or scarcely able to stand, he must give them a little of the milk which at these times he should always carry about him, or he must place them in some sheltered warm place; in the course of a little while, the young one will probably be able to join its dam. The lambing field often presents at this period a strange spectacle. Some of the younger ewes, in the pain, and confusion, and fright of their first parturition, abandon their lambs. Many of them, when the udder begins to fill, will search out their offspring with unerring precision; others will search in vain for it in every part of the field with incessant and piteous bleating; others, again, will hang over their dead offspring, from which nothing can separate them; while a few, strangely forgetting that they are mothers, will graze unconcernedly with the rest of the flock.

'The shepherd will often have not a little to do in order to reconcile some of the mothers to their twin offspring. The ewe will occasionally refuse to acknowledge one of the lambs. The shepherd will have to reconcile the little one to its unnatural parent, or to find a better mother for it. If the mothers obstinately refuse to do their duty, they must be folded by themselves until they are better disposed; and, on the other hand, if the little one is weak and perverse, it must be repeatedly forced to swallow a portion of her milk, until it acknowledges the food which nature designed for its sustenance.'

Male lambs are cut nine or ten days after birth. Weaning, or removal from the mother, takes place from three to four months after birth, according to circumstances. In weaning, the ewes and lambs must be separated so far that they will not hear the bleatings of each other. The lambs are at first put on the tenderest herbage that can be selected. Some ewes may have so much milk, that the udders will swell when deprived of the lambs, and this requires to be attended to by the shepherd at this trying season of his labours.

Food—Tending—Shelter.

The best kind of food for sheep is nutritious grassy pasture, growing on a dry and firm soil. The sheep is most assiduous in picking up food, and will range over a great space in quest of the herbage which it is fond of. In the Highlands of Scotland and in Australia, where the herbage is scanty, the sheep-farm requires to be very large; twelve miles in length and breadth is no unusual size of a Highland sheep-farm. In countries liable to be covered with snow in winter, hay must be preserved for the subsistence of the flocks when they cannot get their ordinary food. Natural meadow-hay and turnips are used in Scotland for winter keep when ordinary resources fail; and the employment of these, in the case of heavy

drifts, sometimes saves large numbers of sheep. If the flock can be conveniently driven to a cleared hay-field, this is done in preference to carrying food to the animals; there should be one field for the rams, and another for the lambs, or for sheep in a weakly condition. A general rule for sheep intended for the butcher is, that they should never be allowed to turn lean, but be kept in a constant state of improvement; and that kind of food should be selected that will bring the animals to the highest condition in the shortest time and at the least expense. In well-managed store-farms, sheep are now allowed many kinds of food little thought of in former times, as sliced turnips, oil-cake, &c.; and are, besides, provided with troughs of pure water, and a trough of salt, that they may lick when their taste leads them to that indulgence.

Heedless farmers are sometimes apt to purchase and keep more sheep than they can conveniently feed on their grounds, which causes a serious evil. To overstock a farm, where artificial food cannot be obtained, is one of the most fatal errors a farmer can commit. A farm may be overstocked for a few years, but death will by and by not only lessen the numbers, but diminish to a great extent the health and productiveness of those that survive. Avarice and ignorance have tempted not a few farmers to carry on this unequal struggle against the laws of nature and humanity for years, but it has always ended, as it ever must, either in the farmer's ruin, or in a reformation of his plan.

The tendency which most sheep have to ramble, renders it necessary for them to be attended by a shepherd and his dog. The duties of a shepherd are very irksome, and require to be performed by a man of firm resolution, good temper, and discretion. To keep the flock within bounds may be troublesome, but much may be done in the way of prevention; and, at all events, the sheep must not be harassed and chased as if they were so many wild beasts. Being naturally of a timid and gentle nature, the sheep ought to be treated with gentleness. Lazy shepherds who do not exercise a judicious foresight in keeping the flock to its ground, try to remedy the evil by hounding or driving the dog after the stragglers, besides giving no small toil to their own limbs in running. We are desirous to lay it down as a rule, which, however, is well known to all good shepherds, that there should be *only a rare and cautious use of the dog*. Much also depends on the dog being of the proper breed, and well trained to his duty. A good dog gives little tongue; he is seldom heard to bark; his great knack consists in getting speedily and quietly round the further extremity of the flock, and then driving them slowly before him in the direction which his master has pointed out. A wave of the hand in a certain direction, and a word, are usually enough as a sign. Under-bred dogs bark at and fly upon the poor animals, chasing them hither and thither without purpose. All such dogs should be destroyed. A first-rate shepherd's dog is invaluable to the store-farmer, and no reasonable price should be grudged to obtain one.

We now proceed to quote a few passages on the 'Winter or Storm Feeding of Sheep,' from an article which appeared in the *North British Agriculturist* in 1853, from the pen of Mr Boyd of Innerleithen. 'One of the greatest errors that can be committed in the management of stock during a storm, is to be too long in commencing the feeding of the flocks. Once allow them to deteriorate, and it will be found no easy matter to restore them again to their wonted health and condition. We have long advocated the propriety of cultivating the whin and broom for the winter-feeding of sheep. . . . . They fill up the blank in green feeding, between the decay of herbaceous plants in autumn and their renewal in spring, and they afford a nourishment more wholesome and palatable than can be afforded to sheep during that interval, with the additional recommendation of being in general suitable to the soil of our pastoral districts. The *Ulex strictus*, or upright Irish whin, has the greatest number of shoots, and being of a less prickly nature than the French or Scotch varieties, it is on that account more relished by the sheep, but from its tender nature, it is extremely apt to be cut down by frost, when the Scotch and French remain unscathed. The whin ought never to be cut, but portions of it should annually be burned, to keep its shoots tender and succulent. . . . . It has long been a well-ascertained fact, that both the whin and the broom possess medicinal properties for the sheep, and in particular act as an antidote for the rot. It may be stated with some truth that whins and broom occupy no space, as it will be found from the shelter they give to the soil, that the quantity of grass is not only much greater, but some weeks earlier than it would have been had there been no whins and broom whatever. The planting of whins and broom may be considered a permanent improvement of no ordinary kind. . . . Every shepherd of experience and observation must have noticed how very superior in condition the lambing ewes and sheep were which had been fed on whins and broom during a storm, to those which had been fed on the best natural or artificial hay. The former, from their healthy brown colour, more resemble turnip-fed sheep than mountain stock. They are also all but exempted from diarrhœa, which the hay-fed sheep are apt to be seized with the moment they partake of the moist pasture, and which not unfrequently reduces them to a condition anything but calculated to secure a successful lambing-time. From the difficulty of procuring hay during the winter-storm of 1852, many were induced to thin their plantations, that they might give the fir-tops to their sheep, and not a few of them found to be true what was many years ago pointed out by Mr Little, that the sheep thrive better upon half hay and half tops than upon whole hay. Salted pea-straw is considered by many superior to hay for the storm-feeding of sheep, as they have found from experience that their flocks are less apt to fall off in condition. It may not be generally known that when pea-straw is given to turnip-feeding sheep, it has not only the effect of communicating to the flesh of the animal a beautiful tint, but at the same time gives a flavour to the mutton which is highly relished by every palate. A few bolls of oats ought to be at the command of the shepherd, to assist, if found necessary, in eking out the hay during the protracted winter.'

In those districts which are exposed to storms, it is important to afford shelter to the flocks. Where there are jutting or overhanging rocks or bushes, the sheep will crowd under their lee, and

so far protect themselves from harm; but where the country is bare, it will be necessary to erect artificial walls or inclosures of turf and stone, to which they can be led in cases of emergency. On the exposed hillsides of Scotland, it is usual to build circular folds, locally termed *stells*, of sufficient size for a *cut*, or parcel of sheep. The stell is a rude inclosure, formed of a stone and turf wall about four feet in height, and is placed on a piece of ground known to be seldom drifted. Besides these, there should be on every sheep-farm ample and conveniently situated folds for the various sortings of sheep, such as for weaning lambs, shearing, and draughting or drawing out any animals required. Such folds are ordinarily constructed of *flakes*, or movable wooden palings, and occasionally of rope-netting.

Washing—Shearing—Wool.

Previous to shearing, all the sheep should be collected, and washed, to rid the fleece of impurities. Mr Boyd makes the following observations on washing and shearing:

'We would strongly recommend that the river-washing of sheep should be abandoned, and that for ever; and that pond-washing should invariably be substituted in its place. . . . The pond ought rather to be small in size than otherwise, so that the heat of the animal's body may have the effect of raising the temperature of the water, which will assist the washing in no small degree. It has long been a well-ascertained fact, that when wool has been so perfectly washed on the sheep's back that it can be put to the machinery without being previously *scoured*, it not only requires less oil in the preparation, but is less apt to *gilt* during the process of manufacture, scours better, and is ultimately an article of greater purity.

'The result of the Edinburgh and Leith wool-sales, by public auction, holds out every inducement to the flock-masters in Scotland who have not hitherto been very particular in the washing of their sheep, to be more so in future, as the best washed clips at these sales have invariably commanded a higher remuneration to the producer than those which had been indifferently washed. The practical manufacturer, in estimating the comparative value of a well and ill washed clip of wool, not only takes into account the quality, but the probable reduction which will take place in reducing the ill washed to the same degree of cleanness as the well washed; and from his daily experience in witnessing the various degrees of reduction which take place in the scouring of the fleeces, he is the best qualified to give an opinion on the subject; as also to give an accurate estimate of the expense of the scouring and drying, besides the carriage of so much filth contained in the ill-washed wool, which cannot, at the most moderate calculation, be less than 1s. 6d. a stone.

'Sheep, after being washed, ought to be driven to a clean pasture-field, and there remain three or four days before they are clipped. Before commencing the shearing of sheep, they ought to be carefully examined, to ascertain whether or not they are really ready for being shorn. Few greater errors can be committed in the management of stock than that of too early clipping. The practice is highly injurious, both to fat and lean stock, and not only retards their improvement, but not unfrequently originates organic disease, both acute and chronic. . . . Sheep invariably lose weight more rapidly by being exposed to the cold in this manner, than by taking no small portion of their food from them; and it is a well-ascertained fact, that if once you allow animals to deteriorate in condition, it requires no ordinary care and attention to restore them to their wonted health and condition. Experiments have been frequently tried with feeding-sheep, by shearing a portion of them early in the season, and allowing the others to remain unclipped for some time longer; and the results have invariably been in favour of those that were last shorn. It will be readily admitted by those who have a practical knowledge of the management of stock, that if too early clipping of feeding-sheep is injurious, it will be still more so to lean hill-stock, which, owing to their reduced condition, are less able to bear the shock of so sudden a transition. Turnip-fed sheep, and those that have been kept in an improving condition during the winter and spring months, are ready for shearing at any time that may suit the convenience of the store-master, provided the weather is suitable for the operation; but widely different is the case with hill-stock, which, generally speaking, deteriorate in condition during the winter and spring months, and whose wool invariably ceases growing sooner or later, which is in a great measure regulated by the weather or the scarcity of food; and under no consideration whatever ought they to be clipped until the new growth of wool, which appears as the pasture gets more abundant, and which acts as a protection from both heat and cold. It is no matter however favourable the weather may be, and otherwise suitable for the shearing of the flocks, if they are not ready for it. When relieved of their winter covering, while the new growth is so thin and short, they are not unfrequently as much distressed by heat as by cold, and in many situations experience great difficulty in finding a place to shelter them from the burning rays of the sun. Nor, in all our experience, have we ever found that the early shearing of hill-stock had the effect of inducing a rapid or an immediate growth of new wool, but rather the reverse. Every shepherd of experience and observation must have noticed that sheep that were not clipped until the middle of July, have a much more abundant and healthier-looking fleece by the latter end of August, than those that had been shorn some weeks before then. The injurious results produced in consequence of early clipping are not confined to the sheep themselves; the lambs, too, are often seriously injured by the falling off of the milk from the ewes, which early clipping never fails to produce.

'In the management of wool, too much care cannot be bestowed to exclude all impurities in rolling it up, which ought to be done in as firm a manner as possible, but without stretching the fleece.'

Mr Walter Buchanan has written directions to the wool-growers of Australia respecting the management of wool, many of which are of general application:

'In order to assimilate the Australian wool as much as possible with the German, in preparing it for market, the fleeces should not be broken,

but merely divested of the breech and stained locks, and so assorted or arranged, that each package may contain fleeces of the same character as to colour, length of staple, fineness of hair, and general quality.

'If the washing has been performed at the same time and place, and with an equal degree of care, the colour of the wool is likely to be uniform, and it will then only be necessary to attend to the separation of the fleeces as to length, fineness, and general quality; but if a large grower has flocks of different breeds, and fed on different soils, care should be taken that the fleeces be separated, first as to colour, and then again as to length of staple, fineness, &c.

'The fleeces being assorted, should be spread one upon another, the neck of the second fleece being laid upon the tail of the first, and so on alternately, to the extent of eight or ten fleeces, according to their size and weight. When so spread, the two sides should be folded towards the middle, then rolled together, beginning at each end, and meeting in the centre, and the roll or bundle so formed held together by a slight packthread. The bagging should be of a close, firm, and tough nature. The material hitherto most generally used has been sail-canvas, which very ill resists bad weather on a long voyage; and when received here, even in favourable condition, is so dry and crisp, that it will tear like paper: a thicker, twilled, more flexible, and tough material would be preferable. The size and form of the package may be in length about nine feet, and width four feet, sewed up on the two long sides and at one end, the other end being left open, and the sheet so formed being suspended, with the open end upwards, to receive the bundles, made up as before directed, which are to be put in one at a time, one of the flat sides of the roll or bundle being put downwards, and so on in succession, being well trod down, until sufficiently filled for the mouth to be closed. This is the German mode of packing; but it is doubtful whether smaller packages, of the dimensions that have been hitherto sent from the two colonies, may not be more convenient for so long a voyage. The operation of screwing should be discontinued where it has been practised, as the screw-pressure, and remaining compressed during the voyage, occasion the wool to be caked and matted together in a manner that is highly prejudicial to its appearance on arrival. The practice also of winding up each fleece separately, and twisting a portion into a band, is productive, in a minor degree, of the same prejudicial effect; and it is to avoid this that the making German bundles of eight or ten fleeces is suggested.'

Smearing—Dipping.

Smearing is a process of anointing the skins of sheep with certain ingredients, principally for the purpose of rendering the animal less liable to injury from winter cold—the unguent being a slight counter-irritant—and of destroying the vermin which lodge among the roots of the wool. Smearing with a mixture of tar and butter was general in Scotland in former times. The proportions varied in different districts; but in general six pounds of butter and a gallon of tar were deemed sufficient for twenty sheep. The time for laying on this salve was in the end of October and beginning of November, before the rams are admitted to the ewes, which, in the mountain farms of Scotland, is in general about the 22d of November. The smearing with butter and tar has very much declined of late years, and other salves have been substituted, as well as baths in which the sheep are 'dipped.' However, many flock-masters now maintain that the only real use of salves and baths is to destroy the vermin adhering to the body of the sheep, and that the growth of wool can only be increased by better feeding. Still the comparative merits of 'dipping' and 'salving' are yet a question among farmers.

DISEASES OF SHEEP.

The sheep in a state of domestication is subject to a great variety of diseases, but the most formidable, and by far the most destructive, is

The Rot.

It is unfortunate that in the early stages of rot the disease gives no external intimation of having commenced its destined fatal career; for it is generally at the beginning of diseases that human skill is most efficacious in arresting their progress. Sheep in the early stages of the rot, however, instead of shewing symptoms of disease and decay, acquire a great tendency to fatten, which has been turned to advantage by Mr Bakewell and others. But after the disease has undermined the general health, the animal becomes listless, and unwilling to move, leaves its companions, and sinks rapidly in flesh; its eye becomes sunk, dull, and glassy; the wool comes easily from the skin; the breath becomes fetid; the bowels variable, at one time loose, with a black purging, and at another costive; the skin becomes yellow, and sometimes spotted with black; emaciation now becomes more rapid; general fever is induced, and death ensues. There are various methods by which practical men endeavour to ascertain the incipient symptoms of the disease, but the two following are the most general:

The first is, by handling the sheep on the small of the back, and if the flesh feel firm and solid, the animal is judged sound; but if the flesh feel flabby and soft, and give a crackling sound when rubbed against the ribs, the animal is unsound. The other method is by examining the small veins at the corners of the eyes, and if they are filled with yellow serum instead of blood, the animal is pronounced unsound; but the greatest practical tact and talent will not always insure success in discovering the early stages of this insidious disease.

Appearances on Dissection.—The whole cellular tissue is filled with a yellow serous fluid; the muscles are pale, and appear as having been macerated, being soft and flabby; the kidneys are infiltrated, pale, and flaccid; the mesenteric glands distended with a yellow serous fluid; the lungs filled with tubercles; the heart enlarged and softened; the peritoneum thickened; the bowels are often distended with water, and sometimes grown together. But the liver is the primary seat of the disease; its whole structure is in different states of disease; one part is scirrhous and indurated, and another soft and ulcerated; and the biliary ducts are filled with flukes. This appears to be the origin of the disease which has involved

so many organs, and effected such a vast derangement of the whole animal frame.

Causes.—In endeavouring to ascertain the cause of this disease, it seems natural to begin by inquiring whether those parasites which are found in such numbers in the biliary ducts of the liver are the cause or effect of the disease. The parasite named the liver-fluke—*Distoma hepaticum*—is of a brownish-yellow colour, and resembles a small sole divested of its fins; in size it may be seen from that of a pin-head to an inch and a quarter in length (see ZOOLOGY, p. 140). It is supposed to be a hermaphrodite. The spawn or eggs, however, are found in great numbers in the biliary ducts of the liver; these eggs are also found in every part of the intestinal canal, are very often seen in the dung of a sound sheep, and are always numerous in that of a diseased one. How flukes reach the liver of the sheep, and where they pass the previous part of their existence, are points not yet determined. Mr Bakewell found that he could at once induce rot in his sheep, by putting them on ground which he had previously flooded for that purpose. Rot is not caused by scanty food, as has often been alleged, for sheep may be starved to death without producing rot; the fact that the sheep has an extraordinary tendency to acquire fat in the early stages of the disease, shews that the causes of it act as a stimulant at first, apparently originating a slight degree of inflammation in the liver, as the first step in the progress of this fatal disease. But the numerous and well-attested facts now obtained from various climes and countries, lead to the conclusion that the nature of the soil and pastures, and the character of the seasons, are the chief agents in causing rot. This view is confirmed by the fact, that rot is most prevalent in wet seasons, and is nearly confined to lands subject to be occasionally flooded with water at certain seasons of the year, and to soils naturally moist and marshy. On moist and level lands of retentive soil, from which water is slowly evaporated by the sun, and under a temperature favourable to the decomposition of vegetable matter when not thoroughly drained, rot may be said to be indigenous; while on dry and hilly lands the disease is unknown. The nature of the plants which the soil produces is not so important as their being kept in a morbid state by that degree of moisture and heat favourable to their decomposition. 'Rot appears every year in Egypt after the falling of the Nile, and it follows and keeps pace with the subsidence of the waters; and annually destroys at least 160,000 sheep. As soon as the waters of the Nile subside, the pastures which were submerged are speedily covered by a tender rushy grass; the sheep are exceedingly fond of it, and they are permitted to feed on it all day long. In the course of a very little time, they begin to get fat, when, if possible, they are sold; their flesh is then exceedingly delicate; but soon after this the disease begins to appear, and the mortality commences. The disease is more frequent and fatal when the sheep are first turned on the newly recovered pasture, than when the ground becomes dried, and the rushy grass harder. But if the sheep pasture in the midst of mud, or on the borders of the marshes and canals, rot attends every step.'

Prevention and Treatment.—If the true cause of rot has been accurately given, every farmer has in his own hands the most efficient means for its prevention; on all lands that can be defended from being flooded with water, and on all lands whose levels admit of thorough drainage, the manner and amount of drainage must be determined by the position of the land, whether level or hanging, and by the character of the soil, and the quantity of the moisture to be removed; and on all these points each farmer must decide for himself, or be guided by the advice of a competent judge. The only indispensable rule is, that the drainage must be thorough, in order to be effectual; and if the drainage is carried to this point, and the sheep are provided with food and shelter during snow-storms, the farmer will have the pleasure to see the rot, that dreadful scourge of his flock, disappear. This important point is established by practical men whose testimony cannot be impeached, that, with proper care, there would be no rotten sheep found, even upon the most spongy lands in the country. The treatment of rot is confined to narrow limits, from the curious fact, that sheep, in the early stages of rot, acquire fat with singular rapidity; and the best thing the farmer can do, as soon as he finds his flock tainted, is to sell them to the butcher for what they will bring in the market. From the condition of the sheep, this forced sale may be attended with considerable loss; but it will be a loss inferior to that sustained in the fruitless attempt to effect a general cure.

Tainted flocks have recovered, it has been alleged, by being sent to pasture on salt-marshes; but though the efficiency of such pasture were admitted, it is a remedy which only a few farmers could obtain. To change the flock to a more dry and elevated part of the farm, when this is practicable, has been attended with favourable results. The free use of salt is universally admitted to be the best medicine within the reach of the farmer for checking the progress of this deadly disease. A pint of salt water that would float an egg poured down each sheep of a large flock, enabled them so to recover, that the whole were sent to market, only a few requiring a second dose. Sir John Sinclair states that at Mr Mosselman's farm at Chenoi, beyond the Wavre, he found that salt was used for sheep, and that by allowing them to lick it, the rot was completely cured. In this disease, the sheep-farmer must direct his energies and care to the prevention rather than the cure, though some of the remedies just mentioned may be of service at the beginning: yet, from the insidious nature of the disease, it may undermine the constitution before it is perceived to an extent that no known remedies can restore; so that every sheep-farmer must rest his hopes of safety, not in curatives, but in the vigorous use of the means of prevention.

Braxy.

Braxy is an inflammatory disease whose ravages are chiefly confined to *hogs*, and those in the highest condition are most liable to be attacked. Braxy, being entirely an inflammatory affection, may be excited by a variety of causes, such as drinking cold water in a heated state; any great or sudden change of temperature; hail, snow, or rain; feeding on soft rank grasses, which are apt to excite fermentation, and by extrication of gas, distend the stomach, thus originating

inflammation, and sometimes producing sudden death by pressure on the diaphragm. One very frequent cause of braxy is that kind of frosty mornings which load the pastures with hoar-frost. The hogs, from feeding chiefly on dry and binding pastures at that season of the year (from November till March), eat the succulent spots of grass laden with hoar-frost very greedily; and thus the temperature of the stomach is so suddenly lowered, that violent inflammation is immediately produced, and death often ensues in a few hours. In the list of the causes of braxy, the improper use of the dog must not be omitted. It is clear that nothing is more calculated to produce inflammation than violently heating a sheep by incessant use of the dog at seasons of the year liable to sudden and great falls of temperature.

Symptoms.—The animal appears uneasy, often lying down and rising up, standing with its head down and back raised, taking no food, but often drinking water; fever then ensues, when the pulse becomes strong and quick, respiration laborious and rapid, the skin hot, and the fleece clapped; the eyes are languid, watery, and half-closed; by and by it ceases to follow the flock, and soon dies.

Appearances on Dissection.—On opening the body, the appearances vary, according to the parts affected. Sometimes only the reed is affected, and all the rest of the viscera appear perfectly healthy, and the flesh not at all affected. In other cases, the effects of violent inflammation are visible through the whole of the viscera, and the entire flesh of the animal is in a state of rapid putrefaction.

Treatment.—The first and most effective remedy is prompt and copious bleeding from the jugular veins; this being effected, the constipation of the bowels must be removed. The best purgative for this purpose is Epsom salts, two ounces for a dose, dissolved in warm water, and followed by thin warm gruels: these remedies will generally prove effectual if applied at an early stage of the disease; but in a large flock of mountain-sheep the disease is frequently not observed by the shepherd till too late for any remedy. Removal to young grass or turnips has been attended with beneficial results. The best preventive of the disease in mountain-sheep is skilful and attentive herding, preventing the young sheep from fastening too much on marshy succulent spots, and seeing they graze regularly over every part of the pasture, and are allowed perfect repose for rumination, undisturbed by the dog.

Sturdy.

The proximate cause of this formidable disease, is the presence in the brain of a parasite of the same class as that which causes rot, and usually called a hydatid. A hydatid is really an early form in the development of the tape-worm, being the embryo of a tape-worm inclosed in a bag or cyst filled with a watery fluid—a *cystic* worm (see ZOOLOGY, p. 140). This hydatid, when given to dogs, is known to produce tape-worms, and conversely itself originates from the ova of the tape-worm ejected on the pastures by dogs, rabbits, or even by sheep themselves. In the state of ova, or in some of its earlier minuter transitional forms, the hydatid embryo is picked up along with the grass. The embryo is provided with spines suited for boring; and with these it perforates the walls of the stomach, and reaches some solid organ, such as the liver or the brain, where it develops for itself the bag or cyst above described. Curiously, the ova are never developed unless thus ejected, and swallowed by another animal. The disease is most common in low damp pastures, and amongst sheep from six to twenty months old. The animal cannot properly seek its food, loses condition, staggers when moved, turns stupidly round almost in one spot, and usually towards the side on which the hydatid lies. The parasite and its sac may generally be safely removed by placing the sheep, with its feet tied, on a table or bench, searching for the softened portion of the skull, which generally overlies the hydatid, laying back a flap of skin, and introducing the trochar and canula, and when the sac is deep-seated, cautiously withdrawing it with the help of a small syringe. Protected by a leather cap and simple water-dressings, the wound speedily heals.

The use of the trephine is attended with some difficulty and danger. It lays open at once an immense space in the brain to the action of the atmosphere, and its consequent irritation, and hence the risk of inflammation. When the situation of the hydatid can be ascertained by the softening of a portion of the skull, to destroy the vitality of the hydatid by perforating it with the trocar or other sharp instruments, is perhaps the method attended with the least danger of exciting inflammation, and hence the most likely to succeed. But the extent to which the disease must have injured the brain, before the softening of the bone could reveal the position of the hydatid, is an insuperable evil, diminishing the chances of success in any mode of conducting the operation that can be devised. There is no medicine that can justly be regarded as of any avail. But carefully observed and accurately recorded facts may yet throw some light on the remote causes of this formidable disease, under that higher anatomical and physiological knowledge which has within these few years been brought to bear on the diseases of our domestic animals.

Pining.

This disease, it is said, was unknown in this country before the sheep-walks were thoroughly drained and the moles exterminated. If this statement is correct, the cause of the malady must obviously be too dry and binding pasture; and in accordance with this view, constipation of the bowels is always present in this disease. To open the bowels freely, and change to young grass, are the obvious remedies; and when both can be readily applied, they seldom fail of complete success.

Dysentery.

This disease begins with violent discharges from the bowels of a green slimy mixture, which in progress of time becomes mixed with blood. It has often been confounded with diarrhœa, from which it differs in many particulars. Diarrhœa attacks young sheep, particularly hogs, occasioned by a sudden rush of grass in the spring, or from too sudden a change from a scanty to an over-rich pasture; when such are the causes of diarrhœa, the mere change to a drier pasture will effect a cure. But dysentery attacks old sheep, and generally does not commence till June or July. Many

writers allege that this disease is highly contagious, but the best established facts do not sustain the allegation. The disease prevails in fouled pastures, and in seasons characterised by a peculiar state of the atmosphere with regard to heat and moisture. In the treatment of this disease, bleeding is a proper remedy in an early stage; but if late, gentle purgatives alone must be used: Epsom salts or castor-oil, with twenty-five to thirty drops of laudanum, are the best. An infusion of logwood and doses of ipecacuanha have also been used with good effect.

Trembling.

Trembling, or *Louping Ill*, is a disease caused in mountain flocks by cold east winds, which are prevalent in April and May, and at which season this disease, after a bad winter, is often very destructive. The animal sometimes leaps from the ground and falls down dead; but more generally it is seized with trembling, loses the power of its legs, and lies on its side, grinding its teeth, and moving its limbs with great violence. The appearances on dissection are very uniform: great congestion of blood in the liver and lungs, and particularly the heart, which is invariably gorged with dark blood; and the brain is also sometimes congested; the whole flesh of the body is as white as if it had been killed by bleeding.

Treatment.—Copious bleeding in the first stage of the attack will often restore the balance of the circulation; but if the animal has been affected some time, it is often difficult to obtain a sufficient quantity of blood, which has been thrown from the surface upon the heart and other internal organs. In this state, the animal must be put into a tub of hot water at 98°, which will cause the blood to flow, and thus restore the action of the heart, and tend to restore the balance of the circulation. After a sufficient quantity of blood has been drawn, doses of Epsom salts, dissolved in warm water, and followed with thin warm gruels, must be given till the bowels are freely opened. The prompt application of these remedies on the first attack of the disease would in general be successful; but, like many other diseases of sheep, it is not observed till the action of the heart has become too feeble for any remedies to restore the lost balance of the circulation. A sudden surprise has been found to produce trembling, so that shepherds cannot be too cautious while turning sheep.

Foot-rot.

This is a disease most prevalent in luxuriant meadows, and in all soft grassy lands saturated with moisture. The opinions entertained regarding its causes are discordant in the extreme. Some writers contend that it is comparatively a modern disease, and was first mentioned by two French physicians, M. Etienne and M. Leibault, who published some cases of the disease in *La Maison Rustique*, in the year 1529. Lulin says that it was brought from Piedmont to Geneva in the year 1786, and that the foot-rot did not exist among Swiss sheep before that period; and in a Report of the management of Flemish sheep in 1763, published by authority, foot-rot is not once mentioned. In our own country, it is mentioned by Sir Anthony Fitzerherbert in the year 1523. But whatever may have been its history and progress in other countries, it was very prevalent in Great Britain in 1749. Ellis, who wrote in that year, says 'that it raged particularly in the counties around the metropolis. The ewes were seized with foot-rot, which was communicated to other sound ewes and to the lambs which they suckled; and most of the meadows are so much infected with this sheep-malady, that few of the suckling ewes are ever clear of it in a greater or less degree, and the pain and anguish thereof keeps them poor in flesh, and lessens their milk; so that two or three ewes thus affected give no more milk than one full milch-ewe that is in perfect health.'

It will aid the reader to follow with greater clearness the following discussions regarding the nature and causes of foot-rot, to have first a correct view of the healthy anatomical structure of the foot of the sheep, at least in as far as this very formidable disease is concerned. 'There are some points of importance,' says the late Professor Dick of Edinburgh, 'to be kept in view, in order to understand properly either the functions of the foot of the sheep, or the nature of the diseases to which it is liable. The foot presents a structure and arrangement of parts well adapted to the natural habits of the animal. It is divided into two digits or toes, which are shod with a hoof composed of different parts, similar in many respects to the hoof of the horse. Each hoof is principally composed of the crust or wall, and the sole. The crust, extending along the outside of the foot round the toe, and turning inwards, is continued about half-way back between each toe on the inside. The sole fills the space on the inferior surface of the hoof between these parts of the crust, and being continued backwards, becomes softer as it proceeds, assuming somewhat the structure of the substance of the frog in the foot of a horse, and performing at the same time analogous functions. The whole hoof, too, is secreted from the vascular tissue underneath. There are, besides, two supplementary digits at the fetlock. Now, this diversity of structure is for particular purposes. The crust, like that in the foot of the horse, being harder and tougher than the sole, keeps up a sharp edge on the outer margin, and is mainly intended to resist the wear and tear to which the foot of the animal is exposed.'

This structure of the foot of the sheep is adapted to Alpine ranges, which are the native abodes of sheep. 'Dwelling by preference,' in the language of Mr Wilson, 'among the steepest and most inaccessible summits of lofty mountains, among its native fastnesses, it is seen to bound from rock to rock with inconceivable swiftness and agility.'

From these facts, it is easy to perceive how our domestic sheep are very subject to foot-rot, when confined to a limited range on soft and rich pastures, and in wet and grassy lands. In these situations, the growth of the crust of the hoof exceeds the wear and tear, and soon overlaps the sole, and in this situation is either rent or broken off, when sand or dirt reaches the vascular parts of the foot, and hence inflammation is produced. The animal then becomes lame, suppuration takes place, and ulcers discharge fetid matter; and if these ulcers go on unchecked, they throw out fungous granulations; and if these be allowed to go on, the hoof falls off. When the disease reaches to this extent, the constitutional disturbance is very great from

high inflammatory fever, and the animal rapidly loses flesh, and, if unrelieved, dies of fever and starvation.

The most approved treatment of the disease is to pare away all the detached hoof, and dress the diseased part with some caustic, perhaps muriate of antimony. But as prevention is in all cases to be preferred to cure, the shepherd should keep a vigilant eye upon the flock, and pare regularly on lands that require it. By the simple means here recommended, the writer has prevented the disease from injuring his flock of sheep for more than twelve years, though the lands were subject to the disease. But if foot-rot be as virulently infectious as it is affirmed to be by a whole host of writers, very different means both of prevention and treatment must be adopted. As the decision of the question, whether foot-rot be infectious or non-infectious, is of great practical importance to every sheep-farmer, the evidence on both sides of the question would require to be stated with perfect candour, in order to arrive at the truth. In so far as evidence has been produced, the argument inclines to the side of those who contend for the non-contagiousness of the disease. Professor Dick asks : 'Has any one ever attempted to produce the disease by inoculation? If it is highly infectious, surely it will at once be produced by inoculation. But this is not such an easy matter as one would expect, from a disease which is supposed to infect a whole field, and that, too, even if it be of five hundred acres in extent. Gohier, a French veterinarian, first applied a piece of horn from a diseased foot, covered with the matter, to the sole of a sound foot without effect; secondly, he rubbed a diseased foot against a sound one without effect; thirdly, he pared the sound foot, and having applied a piece of diseased hoof, the disease afterwards appeared; but in this case the foot afterwards got well of itself, and there seems to have been a doubt in the mind of Gohier as to whether it was truly foot-rot or not. Other French veterinarians have tried similar experiments, and particularly Vielhan of Tulle, and Favre of Geneva; and although I have not seen an account of their experiments, it is said they succeeded in producing the disease by inoculation. Now, it will be asked, Is not this a sufficient proof of its infectious nature? I answer that it is not. It appears to me that this is a strong proof against it. If it is produced with so much difficulty by the direct application of matter, is it not absurd to suppose that a few sheep with diseased feet should infect a whole field? I have not seen an account of the manner in which the experiments of the French veterinarians have been performed; I know not what quantity of matter was employed, neither have we any account of counter-experiments, nor whether any were tried to prove if a similar effect would not have been produced by the application of any other morbid matter; for example, whether the matter of grease from the heels of horses, or from thrushes, would not have produced similar effects. I have little doubt of such being the case; that suppuration might be produced by inoculating with that or almost any other matter, if, in the operation, the wound was made sufficiently deep; nor would I doubt that disease would be produced if matter was spread over the foot in sufficient quantity, and applied for a sufficient time.'

In support of these views, Mr Black, farm-overseer to His Grace the Duke of Buccleuch, states that he had thirteen score of Black-faced sheep, the greater part of which were affected with foot-rot, and many of them crawling about upon their knees. He turned them into a drier pasture, on which were seven score of Leicester and Cheviot sheep. All of the diseased sheep except four speedily recovered, and not one of the Leicesters or Cheviots was infected.

The Scab.

This frequent and very mischievous disease has annoyed the cultivators of sheep in different parts of the world from time immemorial. It is mentioned by Ovid and Livy, and in the *Georgics* it is very graphically described by Virgil. In our own country, it is mentioned by our earliest writers; and in Italy, France, and Germany there is scarcely a writer on sheep who does not describe this prevalent and ruinous disease.

Symptoms.—The sheep becomes restless, scratching itself, tearing off the wool with its teeth, and rubbing violently against any post, stone, or gate. When the skin is carefully examined, there are seen numerous pustules, which, having broken and run together, form large patches of scab. The back and shoulders are generally first affected. The general health of the animal sinks in proportion to the extent of the eruption and the virulence of the disease, and if allowed to proceed unchecked, it brings on general inflammation, and the animal dies in a most miserable condition.

It is now ascertained that this disease in sheep is caused by minute *acari*. M. Walz, a German veterinarian, has given a very curious and interesting account of the operations of these acari, which are said to burrow in the skin of the sheep, and reappear again about the sixteenth day with a numerous brood. These young insects commence operations at once, and propagate in the same manner, till the poor sheep sinks under myriads of his destroyers.

The treatment of scab is very simple—the destruction of the insect which causes it. An infusion of tobacco, hellebore, and arsenic, have all been employed with success. In bad cases, mercurial ointment has been applied with the happiest effect. A very good recipe is a decoction of tobacco and spirit of turpentine, with a little soft soap and sulphur vivum.

The only caution necessary to be given in the use of any of these remedies is, to take care that they be brought thoroughly in contact with every part of the skin of the affected animal, lest any of the burrowed acari escape. And all folds or sheds in which infected sheep have been confined, and all gates, posts, and other rubbing-places, must undergo thorough purification. Besides the acari, sheep are liable to be attacked by various other insects, such as the flesh-fly, and a species of aphis called the sheep-louse. The maggots of the flesh-fly only prevail in the moist and warm summer months, but increase in numbers with amazing rapidity, and require great watchfulness on the part of the shepherd, as they soon destroy a large portion of the skin and flesh of the sheep if unchecked. The aphis also creates great irritation; but both are easily destroyed by any of the preparations already detailed. The tick (*Acarus reduvius*) is also a very formidable insect to

sheep. It almost buries itself in the skin, and adheres so firmly by six legs, very muscular and powerful, and so armed with serrated claws, that it can scarcely be disengaged from its hold, but it will yield, like most of the parasites which infest the sheep, to the application of a mercurial preparation.

Statistics.—According to the statistical returns furnished to the Board of Trade, the number of sheep and lambs in Great Britain and Ireland amounts to nearly thirty-one and a half millions, which may be estimated to produce fully 130,000,000 pounds of wool. The imports of wool must amount to as much more; but a considerable quantity is again exported, chiefly to France and Germany. Most of the fine wool for the manufacture of broad-cloth was at one time derived from Saxony and other German states, where the Merino breed of sheep is cultivated with great success; but this trade has of late almost ceased, and German dealers, in their turn, now attend the London sales of Australian wool in order to supply their own wants. The total number of sheep in the Australian colonies was stated in 1854 at 17,000,000; but in 1870, including New Zealand, the number has tripled, as they now amount to 51,000,000; while at the Cape of Good Hope and Natal there are upwards of 10,000,000. The weight of a fleece of wool is from 1½ to 3½ pounds; and the value varies, according to the quality and state of cleanness, from 6d. to 3s.; that of clean Australian wool may be stated at 2s. 6d.

THE GOAT.

The Goat belongs to the same family of *Ruminants* as the sheep. The common domesticated goat is usually about the size of the sheep, though less round in form, and is marked by keen eyes, long hair, and generally bent horns. The males, called familiarly in England *billies*, have a long beard; but the females, or *nannies*, are seldom provided with that appendage. Whether in a state of nature or tamed, the goat is remarkably swift and agile, and will browse fearlessly on the most rugged precipices. We find, from ancient writers, that goats have long formed part of the stock of mountain herdsmen, and were tended with even greater care in former than in present days. In many respects, indeed, the animal is valuable. Its skin is convertible to several useful purposes, and the flesh of the full-grown goat is good, though scarcely equal in quality to that of the sheep. But it is for the milk chiefly that the goat is prized; the qualities of that secretion being not only very nutritious, but even medicinal. Where cottagers have not the means of keeping a cow, a goat will be found a very useful animal, being easily fed, and contented with grasses which are rejected by the cow and the sheep. To those peasants who live in mountainous countries, the trouble and expense of keeping a couple of goats is next to nothing, as they find sufficient nourishment in the most heathy, rough, or barren grounds, and require no care or attention. In some countries, goats are of considerable service to mankind, the flesh being salted as winter provision, and the milk used for the making of cheese. The flesh of the kid is highly palatable, being equal, if not superior in flavour, to the most delicate lamb.

In Britain, the goat produces generally two young at a time; sometimes three, rarely four. In warmer climates, it is more prolific, and produces four or five at once, though the breed is found to degenerate. The time of gestation is five months. The male is capable of propagating at one year old, and the female at seven months; but the fruits of a generation so premature are generally weak and defective; their best time is at the age of two years, or eighteen months at earliest. A goat is accounted old at six years, although its life sometimes extends to fifteen.

If goats are properly trained, they will return to their owners twice a day to be milked, and prefer sleeping under a roof when accustomed to it. The milk of the goat is sweet, and not so apt to curdle upon the stomach as that of the cow; it is therefore preferable for those whose digestion is weak. The peculiarity of this animal's food gives the milk a flavour different from that of either the cow or the sheep. The quantity of milk produced daily by a goat is from three half-pints to a quart, and it yields rich and excellent cream. If properly attended to, a goat will yield milk for eleven months in the year. In some parts of Switzerland, Wales, and the Highlands of Scotland, the goat is one of the chief possessions of the inhabitants. On mountains where no other useful animal could find subsistence, the goat contrives to glean sufficient living, and supplies the hardy natives with what they consider a varied luxury. They lie upon beds made of their skins, which are soft, clean, and wholesome; they live upon their milk, with oat-bread; they convert a part of it into butter, and some into cheese; and the flesh furnishes an excellent food, if killed in the proper season, and salted. Goats are fattened in the same manner as sheep; but taking every precaution, their flesh is never so good nor so sweet as mutton. It is otherwise between the tropics. The sheep there becomes flabby and lean, while the flesh of the goat rather seems to improve. The cream of goat's milk coagulates as easily as that of cow's, and yields a larger proportion of curd. The cheese is of an excellent quality, and high flavoured; and although to appearance it looks poor, it has a very delicate relish, and strongly resembles Parmesan cheese. Some farmers are in the practice of adding a little goat's milk to that of cows, which materially improves the flavour. In winter, when native food becomes scarce, the goat will feed upon turnip-peelings, potato-peelings, cabbage-leaves, and other refuse of a house. In addition to the other products yielded by the goat, its tallow is an article of some importance. It is much purer and finer than that of sheep, and brings a high price, making candles of a very superior quality.

Cobbett advocates the keeping of a goat by cottagers. 'There is one great inconvenience belonging to goats—that is, they bark all young trees that they come near; so that if they get into a garden, they destroy everything. But there are seldom trees on commons except such as are too large to be injured by goats; and I can see no reason against keeping a goat where a cow cannot be kept. Nothing is so hardy; nothing is so little nice as to its food. Goats will pick peelings

out of the kennel and eat them. They will eat mouldy bread or biscuit, fusty hay, and almost rotten straw, furze bushes, heath thistles, and indeed what will they not eat, when they will make a hearty meal on *paper*, brown or white, printed on, or not printed on, and give milk all the while! They will lie in any dog-hole. They do very well clogged, or stumped out. And then they are very healthy things into the bargain, however closely they may be confined. When sea-voyages are so boisterous as to kill geese, ducks, fowls, and almost pigs, the goats are well and lively; and when no dog of any kind can keep the deck for a minute, a goat will skip about upon it as bold as brass.'

In Britain, no attempts have been made, at least successfully, to introduce foreign breeds of goats, although in France this has been done to a considerable extent. The Cashmere goat, famous for its long silky hair or wool, has been brought to France, and there bred with the Tibet goat, a hardier species, but almost equally esteemed for its wool. The manufactures producible from this material, as the Cashmere shawls have long testified, are scarcely to be surpassed for fineness, and yield immense prices. It is probable that, in our warmest districts, a cross of these foreign goats with the common breed might be successfully and advantageously effected.

THE ALPACA.

This animal, an inhabitant of the Andes below the line of perpetual snow, belongs to the family of the *Camelidæ.* Naturalists are not agreed whether it is a distinct species, or merely a variety of the Llama, which was used as a beast of burden by the native Peruvians. The Paco, or Alpaca, has the wool or long hair more developed than the other species or varieties, whichever they may be. The wool is much prized for its silky fineness, length, and lustrous appearance. Nearly 4,000,000 pounds of Alpaca wool are now annually imported into Britain, where it is used in the manufacture of shawls, coat-linings, cloth for warm climates, umbrellas, &c. Some years ago, attempts were made to naturalise these animals in Britain, but with little success. Their introduction into Australia has also been attempted, with little advantage. They are naturally suited for mountainous districts in a climate rather milder than that of Scotland. They are said to be diminishing in number in their native country, and to threaten, before long, to become extinct.

The Alpaca.

Poultry.

PIGS—RABBITS—POULTRY—CAGE-BIRDS.

PIGS.

THOUGH, relatively speaking, the pig may not be of the same importance to the rural population as it once was, yet, to the humbler classes, the ancient adage, that it was second only to the cow, cannot be regarded as inapplicable. As an object of natural history, it ranks with the *Pachydermata*, or thick-skinned order of the Mammalia—the hog, wild-boar, and probably also the peccary of South America, being varieties of the same family. The most remarkable characteristic of the common pig is its long roundish snout, furnished with a strong cartilage at the extremity, for the purpose of grubbing in the earth for roots and other kinds of food. The feet are cloven, and each possesses four toes, two of which are large, and furnished with stout hoofs, the other two being small, posteriorly situated, and scarcely touching the ground. The body is of a cylindrical form, low set, and thinly covered with bristles, which rise into a mane in some of the ancient varieties. The tail is small, short, and in general twisted, and in some breeds is altogether wanting; the ears are either large and pendulous, or short and pointed. The jaws of the pig are powerful; and the teeth with which they are furnished are very formidable, particularly in the wild varieties. Swine do not ruminate (chew the cud); and from this and other peculiarities, they can feed either on vegetable or animal substances—thus forming a kind of link between the herbivorous and carnivorous classes of animals. They are, in fact, omnivorous, and scarcely any sort of food comes amiss to them.

THE DIFFERENT BREEDS AND MANAGEMENT.

The more popular breeds of pigs in Britain are the Berkshire, the Yorkshire, the improved Chinese, and the improved Essex. Few will grudge the preference to the Berkshire. It is a very valuable pig—grows to a great size, comes early to maturity, is small and fine in the bone, low on its legs, and very superior both as regards quantity and quality of flesh. The colour is almost black, with a little white about the face, head, and feet. One instance is on record of a Berkshire hog, fed by Mr Lawton of Cheshire, measuring 9 feet 8 inches in length, and 4 feet 5½ inches in height, and weighing, after being slaughtered and dressed, 86 stones 11 lbs. The Yorkshire pig is an animal which invariably grows to a great size. It stands high on its legs, is very long in the snout, head, and body. It has more bone than some other breeds; but its growing capacities, its inclination to 'shift' for much of its food, and valuable bacon-forming properties, render it a favourite even beyond the great county from which it derives its name. While the ear is moderately sized, the

colour is white, the bristles long but thin, and the skin often red, and somewhat tender. In the north of England, droves of pigs, mostly of this breed, may be seen in the parks among the cattle. The Chinese breed is small in size, cylindrical in form. The back is a little hollow, and the belly slightly projecting. The ear is small, and so are the bones. The bristles are as soft almost as hair, and the colour is generally white. The head and face resemble more those of a calf than any of the other specimens of the porcine tribe do. The Essex pig is popular in a considerable portion of England, though it has not been very numerously introduced in Scotland, except, perhaps, in the shape of a cross. The Essex pig is up-eared, has a rather long snout, a lengthy fleshy carcase, with small bone. The colour is invariably black, and the skin is almost destitute of hair. For long this breed had to contend with a sort of prejudice against them, as being restless, ill to feed, and not calculated to develop in accordance with the amount and value of the food they consumed. In neither of these respects, however, are there any complaints now; and at the Royal Agricultural Society of England's shows, as well as in the Smithfield and Birmingham fat-stock exhibitions, many beautifully plump, portly porkers of this variety enlist public notice.

Then the old Scotch pig claims a word. It is comparatively small in size; generally white or gray in colour; long in reaching maturity, and calculated to feed on almost any sort of food. It is not very fine in the bone, nor so plump nor flesh-producing as the Berkshire and some of the more fashionable breeds; but it has been a valuable animal in its day and generation, and still exists in considerable numbers in Orkney and Shetland, and in the Western Isles.

The Irish pig of bygone years was a tall, leggy, bony, somewhat coarse-coated, heavy-eared animal, often imperfectly fed, yet generally in fair condition. By the introduction of improved breeds from England, and more careful breeding, the Irish pig, as well as the native Scotch pig, has been immensely improved—assimilated much more to the English varieties. Besides those enumerated, there are the huge breeds of the midland counties—of Sussex, Shropshire, Cheshire, &c. which form attractive features in our national show-yards, alike in respect of their colossal proportions, and unmistakable evidences of careful breeding and high feeding.

Some of the best pigs in the country are the result of judicious crossing with the principal breeds. In Scotland, for instance, many of the swine are not of any pure breed, but the old native animal vastly improved by the infusion of a dash of higher blood. This improvement system has not yet proceeded so far over the country as it should, and will soon do, in the interests of all concerned.

The Selection of Breeding-pigs.

The following points, enumerated by Mr Richardson, deserve the attention of every one about to select breeding-pigs. 'In the first place, sufficient depth of carcase, and such an elongation of body as will insure a sufficient lateral expansion. Let the loin and breast be broad. The breadth of the former denotes good room for the play of the lungs, and a consequent free and healthy circulation, essential to the thriving or fattening of any animal. The bones should be small, and the joints fine. Nothing is more indicative of high breeding than this; and the legs should be no longer than, when fully fat, would just prevent the animal's belly from trailing upon the ground. The leg is the least profitable portion of the hog, and we therefore require no more of it than is absolutely necessary for the support of the rest. See that the feet be firm and sound; that the toes lie well together, and press straightly upon the ground; as also that the claws are even, upright, and healthy. Many say that the form of the head is of little or no consequence, and that a good pig may have an ugly head, it being no affair of anybody but the animal himself which has to carry it; but I regard the head of all animals as one of the very principal points in which pure or impure breeding will be most obviously indicated. A high-bred animal will invariably be found to arrive more speedily at maturity, to take flesh earlier and with greater facility, and altogether to turn out more profitably than one of questionable or impure stock; and such being the case, I consider that the head of the hog is by no means a point to be overlooked by the intending purchaser. The description of head most likely to promise, or rather to be the concomitant of, high breeding, is one not carrying heavy bone, not too flat on the forehead, or possessing too elongated a snout—indeed, the snout should, on the other hand, be short, and the forehead rather convex, recurving upwards; the ear, while pendulous, should also be inclining somewhat forward, and at the same time light and thin. Nor would I have the buyer pass over even the *carriage* of a pig. If this be dull, heavy, and dejected, I would be disposed to reject him, on suspicion of ill health, if not of some concealed disorder actually existing, or just about to break forth. Nor is colour to be altogether lost sight of. In the case of pigs, I would, as in reference to any other description of live-stock, prefer those colours which are characteristic of our most esteemed breeds. If the hair be scant, I would look for black, as denoting connection with the delicate Neapolitan; but if too bare of hair, I would be disposed to apprehend too intimate alliance with that variety, and a consequent want of hardihood, that, however unimportant, if pork be the object, renders such animals hazardous speculations as stores, from their extreme susceptibility of cold, and consequent liability to disease.'

One cannot be too careful in the selection of proper stock to breed from. If the desire is to get early into the market, and to produce pork, the varieties most likely to take on flesh quickest, and come earliest to maturity, should be chosen. If, on the other hand, bacon is the object, the larger breeds are the most suitable. In any case, the boar should be rather less in size than the sow, and more compact and hard in the flesh. With pigs, as with cattle-breeding, what is called 'in and in' (that is, with animals of close consanguinity) is disapproved by most people, as calculated to decrease the size of the progeny, and weaken the constitution. Several instances could be pointed to of successful close breeding of this kind among cattle, but few among pigs; so that in the case of the latter, at anyrate, it should be, and generally is, studiously avoided.

To secure a good strong plant and a vigorous progeny, pigs should not be allowed to breed during the first year of their existence.

The sow is very prolific, compared with other large-sized quadrupeds, and for that end is provided with from twelve to sixteen teats. Her period of gestation is sixteen weeks; the number of young varies considerably, being frequently below ten, and occasionally rising to twenty. The young pig is exceedingly delicate; and the brood sow should not be allowed to farrow in winter, but in spring and autumn, when the weather is less severe, and food more abundant. Another peril to the litter arises from the semi-carnivorous habits of the mother, which lead her to forget the duties of nature, and devour her own brood. She ought, therefore, to be well watched, and fed abundantly at such periods. The male, for the same reason, must be excluded altogether. Not unfrequently, moreover, the young are crushed to death by the mother, in consequence of their nestling unseen below the straw. To prevent this risk, a small quantity only of straw, dry and short, should be placed below them. The young are weaned when six weeks old; and after weaning, it is essentially necessary to feed them with meal and milk, or meal and water, or whey.

Many persons labour under the notion that swine, while breeding, should be kept lean; but nothing can be more erroneous; for, after farrowing, great part of those juices which would be converted into milk, were she in good condition, will naturally go towards nourishing her system. When required for the purpose of fattening, the male young pigs are cut, and the females sometimes spayed, which is an analogous process. These operations should always be intrusted to a farrier or other properly qualified person. At weaning-time, it was also customary to 'ring' the young pigs; that is, to insert a ring of iron in the cartilage of the nose, to prevent the animal from grubbing and turning up the floor of the piggery. In pigs intended to be turned to the woods or fields, this process was especially necessary; and where requisite, is preferable to the barbarous and less effectual plan of cutting off the cartilage altogether. Though still done to a considerable extent, the ringing is not now so common as it was; the improved construction of piggeries, and the diminution of the herds and droves in woods and fields, rendering it less imperative.

Pig-houses.

The results which attended the better housing, more careful breeding, and higher feeding of pigs in comparatively recent years, have convinced most people that any rickety structure is not sufficient even for the accommodation of swine. For many years, country-people regarded the pig as the dirtiest, and least to be cared for, in the way of housing, of all the animals in their possession, and treated it accordingly. Probably few animals are less fastidious about the source from which their food comes, or how it is prepared, than the common pig; but if properly attended to, the natural habits of the pig are more cleanly than was generally supposed. The pig-sty should be preserved in the driest, cleanest possible manner; the food regularly and judiciously supplied; and the skin of the animal curried frequently. The miserably built, open-thatched, imperfectly littered pig-house of old is fortunately of rare occurrence nowadays. Improvements are gradually progressing over the country in the housing and feeding of pigs; and the progress has been accelerated by the fact that, in proportion to its advancement, the mischievous propensities of the animal are diminished.

Improved piggeries on a first-class farm should consist of three kinds—namely, for breeding, for feeding, and for weaned pigs. A few months ago, a writer thus described the piggery of Messrs John Moir and Sons, Garthdee, Aberdeen, where about fifteen hundred pigs are kept: 'In two large sheds and courts are about two hundred and fifty breeding-sows of various ages, sizes, conditions, and breeds. In addition to this accommodation, there are one hundred and four pens or boxes, floored with asphalt and Caithness pavement, heated by steam-pipes, and conveniently arranged in four or five double rows. These pens are used by the young pigs, the boars, and the animals undergoing the finishing-touch in feeding. The breeding-stock is fed twice a day, and those preparing for slaughter thrice.' The breeding-sty should be about six feet by eight or nine feet, and the yard in front a little larger. Rather less space may do for the feeding-pigs, if only a pair be intended to feed together. The accommodation for newly weaned pigs should be at least double the size specified above. Swine can scarcely be too much exposed to the sun, in whose rays the animals are fond of basking. Pigs like heat, as is proved by the manner in which they—especially the higher-bred ones—bury themselves among the straw or litter in cold weather. The wooden and paved floors of the piggeries are being to some extent superseded by the introduction of asphalt, which proves satisfactory, if litter is fairly plentiful.

Fig. 1.—Crosskill's Feeding-trough.

In the more modern piggeries, as at Garthdee, a perfect system of draining away the liquid manure has been introduced, and also a supply of water for flushing purposes.

An excellent form of feeding-trough is now much used. That part of the trough in the inside of the yard is divided with partitions, reaching some distance into the yard, so that each pig can quietly take its meal without being forced away by a stronger animal, as is often the case in ordinary troughs, where they all feed in common. Another contrivance is also attached, by which the inconvenience occasioned to the attendant in filling the ordinary trough is obviated. Part of the trough being outside the sty, a swing-door or iron plate is suspended on hinges from its upper end; when this is pushed forward towards the yard-side of the trough, and kept in this position by a catch, the pigs cannot obtain entrance; the whole of the trough is therefore exposed to the attendant, so that he can easily place the food without being annoyed by the pigs. When filled, the swing-door is pulled towards the outside, and there kept by the catch, and the pigs have free access to the trough. The form of feeding-trough on this principle is shewn in the preceding figure. It is built in the wall of the sty, and may be used to feed pigs on either side. A good form of feeding-trough for a yard is the circular one, divided into compartments; these being extended radially for

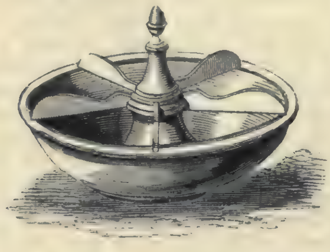


Fig. 2.—Circular Pig-trough.

some distance, forming a series of stalls admitting only one pig at a time. The figure represents Ransomes and Sims' circular trough for feeding pigs in an open court.

Feeding.

A number of pigs are still allowed to cater the bulk of their food in rural districts, especially of Scotland, during summer, but not nearly so many as once were herded in this way. The most of the pigs now are kept the whole year in sties, and 'hand-fed.' To many cottagers, the keeping of a pig or two is an important matter. When a pair of young pigs are purchased by a cottar or small farmer, one is sold when ready for the butcher, weighing from seven to fourteen stone, and the money received for this one defrays the buying-price of the two, and also any outlays for artificial food required beyond the wastes of the holding. The second pig is thus free, and is killed for use in the feeder's family over winter, and highly prized it is by them. Unless for delicate pork, it should not be killed less than a year old. During the summer, the pig may be fed on any refuse from the kitchen or garden, including turnip and potato parings, table-waste, cabbage-leaves, &c.; but if barley-dust, or grains from a distillery, can be economically procured, either forms a good article of diet. Let it be kept in remembrance that the finer the feeding, the finer will be the pork. The food should, at all events, be of a vegetable kind, or principally so; nothing beyond refuse from the table being advisable in the shape of animal food. Whatever be given, let it be offered in small quantities, and frequently, it being a matter of importance never to allow the pig to become violently hungry, nor to have food lying long in the trough. The food should be carefully salted and seasoned; the trough cleaned out before each meal, the diet varied occasionally, and the animals fed separately according to their ages, sizes, conditions, and destinations. Breeding-pigs, or those intended for bacon, should not be very highly fed at first. Let the quantity of bran and succulent roots used in the diet be guided by the state of the dung-cast.

Farmers possess considerable advantages for feeding pigs. In folds among young store-cattle, during winter, pigs thrive exceedingly well. They get abundance of heat, lying as often as they can between two or more of the cattle: nor are the cattle any the worse for their porcine companions. The food of the pig kept in this way is scarcely appreciable. Pigs intended for slaughter about Christmas, which is the best time to kill them, should be fed on particularly nourishing material during the autumn. If for pork, the feeding need not be quite so high as for bacon. In any case, let the bulk of the food be of a hard, substantial character, such as oats or meal, for some weeks before killing. Boiled potatoes mixed with a handful or two of meal, the last month or two, are a very common feed at the numerous small farms and crofts, especially in Ireland and Scotland, and produce very fine pork, though not so fat as that raised from such hard food as barley, bean, or pease meal. Above all, the half-starving system should be carefully avoided. Repaid as it is by a miserable carcase scarcely worth slaughtering, it is naturally approaching extinction, and cannot reach that goal a day too soon. In fact, there is almost as much oppression occasioned to pigs in these times by excessive as by inadequate feeding. Indeed, many of the huge specimens exhibited at the leading shows appear as if positively suffering from obesity. Not only are they unable to walk, but some of them are quite blind, the eye being buried in three or four inches of actual fat. Nearly all that is visible of the head are the snout and ears.

The most approved modes of curing and preparing pork, brawn, bacon, and hams are detailed in the number on FOOD—BEVERAGES.

Diseases.

The pig is naturally a very healthy animal, and, if at all carefully fed and properly tended in the domesticated state, is not addicted to disease. But if neglected either in feeding or housing, the principal diseases to which they are liable are—fever, leprosy, tumours, murrain, measles, foul skin, mange, crackings of the skin, staggers, indigestion or surfeit, lethargy, quinsy, inflammation of the lungs, catarrh, and diarrhœa. The only general prescription that can be given—beyond greater attention to cleanliness and warmth in housing, and to the regulation of diet—is to call in the services of a veterinary surgeon.

RABBITS.

Rabbits belong to the family *Leporidæ*, members of the *Rodentia*, or Gnawing Order of animals. Their form and appearance are too well known to require any special description. In a wild state, rabbits live in holes in the earth; and where the proprietor permits of their accumulation for sport or for sale, they collect in great numbers, undermining with their burrows whole plains or tracts of land, and forming what are called *warrens*. Their amazing fecundity renders the keeping of a few of them in a tame state an object of some consequence in cottage economy. The rabbit litters seven times in the year, and generally produces eight young at a time. At the age of five months, the animal begins to breed; and taking an estimate perfectly within bounds, it is supposed that a pair of wild rabbits, which breed no oftener than seven times in a year, would multiply in the course of four years to the amazing amount of a *million and a quarter*, if the young were preserved. Many of them die, however, being injured by cold and damp, or are devoured by the male or *buck*.

Experienced rabbit-keepers conceive too frequent breeding to be injurious; but even when proper rules are observed in this respect, three domesticated females (*does*) and a buck will, it is calculated, give a family a rabbit for dinner almost twice a week. A stock of rabbits is easily set agoing, the price seldom exceeding a shilling each. It is of importance, in making such a purchase, to attend to the varieties which feed kindly and furnish the best flesh.

The short-legged stout rabbits are generally supposed to be the most healthy and also the best breeders. The large hare-coloured variety is much esteemed by some people; but the white, or white mottled with black or yellow, are more delicate in flesh. The gray, and some of the blacks, approach nearer to the flavour of the wild rabbit than any others. With respect to the colours of these animals, gray is considered the worst of all colours; black is the next in gradation; fawn, and white, and gray, hold the third place in estimation; pure white, with red eyes, is by some reckoned equal, and by others superior, to these; tortoise-shell—a rich brown and white, and brown, gray, and white—and black and white rank the highest; a uniform mouse-colour, though little noticed by fanciers in general, is much admired by a few. The most important part of the duty of the rabbit-rearer is to erect his rabbit-house or hutch on proper principles. Two objects are particularly necessary to be attended to—the house or rabbitry must be kept always dry and well aired, because the animal, in its natural state, prefers a dry and airy habitation. We give a sketch (fig. 3) illustrative of the accommodation and arrangements likely to prove efficient aids in rearing rabbits economically and healthily: *aa* is the line of wall of house against which the rabbitry is supposed to be erected, or it may be in an isolated position; *b* is the principal door by which the rabbitry is entered. The hutches are placed as at *f, f, g, g*, with a passage between; the floor of each hutch must be lined with zinc, or made of asphalt or flag, to prevent the animals burrowing. The hutches for the breeding-does, *g, g, f, f*, should be contiguous to those for the young rabbits, *g′, f′*; the partitions between them being capable of removal; or small doors may be made through which the young rabbits can pass to the breeding-hutches, *g, g, f, f*; or, if necessary, be isolated therefrom. The floors of all the hutches should slope towards the centre of the passage, so as to lead the liquid manure at once

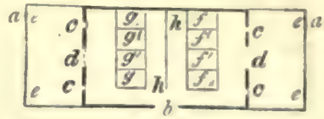


Fig. 3.

to a drain, *h, h*, which conveys it away to a small manure-tank. The application of this to the rabbits' recreative ground, *ee, ee*, surrounded by wire-fence, will keep up a fine crop of grass, amongst which they will rejoice. The food is supplied to the hutches through doors opening into the passage. Each hutch should have the front made entirely of wire, to admit plenty of light, which gains admittance through the windows, *c, c*; *d, d* are the doors through which the rabbits find entrance to the grass-plot, *ee*.

The subject of feeding the tame rabbits cannot receive too much attention. As in the case of most other animals, there is a danger in giving them too much food at a time. Feeding thrice a day is often attended by good results, though many people consider twice a day sufficient. The *Boy's Own Book*, treating on this subject, says: 'Almost all the vegetables and roots used for the table may be given to rabbits: in preference to all others, we choose celery, parsley, and the roots and tops of carrots; and in this choice the animals themselves heartily agree with us; lettuces, the leaves, and, what are much better, the stumps of cabbages and cauliflowers, they eat with avidity, but these must be given to them with a sparing hand; turnips, parsnips, and even potatoes in a raw state, we occasionally afford our stock, on an emergency, when better roots or good greens are scarce. In the spring-time, no soft meat is better for them than tares, so that they be not wet; in fact, no green meat ought to be given to rabbits when there is much moisture on its surface. We have heard of some country persons feeding their rabbits on marsh-mallows, but we never did so ourselves. Dandelions, milk-thistles, or sow-thistles, we know, by long experience, they take in preference to all other food, except celery, parsley, and carrots; and nothing, as green meat, we are convinced, can be better for them.

'It must be remembered that a doe will eat nearly twice as much when suckling as at other times; and when her litter begin to eat, the allowance of food must be gradually increased.'

When rabbits are to be used as food, it is commonly deemed beneficial to feed them for a short time on hay, and afterwards on shellings and oats, when the flesh will grow very delicate in flavour. The case of a labouring man in the country may be mentioned, who, in a small wooden house inclosed by a railing, fed a batch of rabbits, and killed annually about twenty dozen, still maintaining his stock unbroken. What with the skins, flesh, and sales of the young, he turned the animals to good account; yet he scarcely expended a penny upon their food and attention.

The wild rabbits, by their destructive propensities, extraordinary fecundity, and natural dexterity in evading the contents of the rifle, have awakened the ire of every farmer on whose possessions they numerously tread. They undoubtedly are very destructive on almost all kinds of crops the farmer produces. In fact, their existence to any appreciable extent runs in the teeth of good and successful farming. Except, therefore, in cases where the farmer or parties aggrieved have full power to enter the warrens, ferret the burrows, and thus keep the rabbits few in numbers, all warrens or rabbit preserves should be thoroughly fenced; and it is no ordinary fence that will defy a rabbit.

POULTRY.

Poultry (from *poule*, French for hen) is a term applied to different kinds of large birds in a state of domestication; as the chicken or barn-door fowl, turkey, duck, goose, pea-fowl, and guinea-fowl.

COMMON FOWLS—BREEDS AND MANAGEMENT.

The common fowl is classed by naturalists in the tribe of the *Gallinaceæ*, forming part of the order *Rasores*, or Scraping-birds (see ZOOLOGY). The most prominent characteristics of the cock, or male bird, are a thin indented comb, with wattles on each side under the beak; a tail rising in an arch, and a great variegation of colours. The female, or hen, is smaller as regards body, comb, and wattles, and her tints are less vivid. The domestication of this useful bird seems to have taken place in the earliest times, and Persia is commonly supposed to have been the country of its origin. The best marked varieties are the following: The Dunghill Fowl, Game Fowl, Dorking Fowl, Brahmaputra, Houdan, Crevecœur, La Flèche, Polish Fowl, Spanish Fowl, Malay Fowl, Hamburg Fowl, Cochin-China Fowl, and Bantam.

The first of these varieties is a mongrel one, arising from crosses with the other breeds. The best fowls of this sort are of middle size and dark colour, and have white, clean legs; the pure white dunghill fowls are held to be the weakest in constitution, and to lay fewest eggs. Comparatively few of the white fowls exist now. Indeed, the number of barn-door birds of any colour has been decreasing for some time in this country; and the Dorking and other more fashionable varieties increasing in a corresponding ratio.

The game bird has occasionally been termed the proper English fowl. It is indeed a princely little bird, with body erect and slender, and the colour, of the male bird especially, showy. As the race-horse in appearance is to the Clydesdale or Cleveland horse, so, it has been said, is the game bird to other fowls. The flesh of the game fowl, though, of course, comparatively deficient in quantity, is peculiarly white, and delicate in flavour; while, if small, the eggs are of superior quality. But the extremely pugnacious spirit of this fowl, which led to its name, impairs its usefulness to a great extent. So inherent is this fighting propensity, that broods scarcely feathered are found occasionally to have reduced themselves to utter blindness by reciprocal battling. Even when the breed is crossed and recrossed, a tincture of the love of fighting still remains, rendering such admixtures the source of risk and trouble, though in other respects advantageous. Where persons prefer to have a game-cock in their poultry-yard, their choice, according to the best authorities, should be directed to a bird of one or other of the following colours: dark-red, dark black-breasted red, dark-gray, mealy-gray, and reddish-dun.

The Dorking fowl derives its name from a town in Surrey, where it has long been reared in great numbers. It is a large bird, well shaped, with a long capacious body, short legs, and five claws upon each foot instead of four. One spur characterises other breeds of the common fowl, but the Dorking fowl has two spurs on each leg. These distinctive marks seem to be of old standing in peculiar breeds, as both Aristotle and Pliny mention five-toed fowls. Though, from repeated crossings, the Dorking fowls are now found of different colours, white or yellowish-white is supposed to have been the primitive and genuine tint. They lay good-sized eggs, and in great plenty; and have grown in popularity greatly over Scotland in particular within the last fifteen years. They occupy the place of honour at the leading poultry-shows, which is evidence of their generally recognised superiority. The Dorkings come early to maturity, lay early, and are good nurses. They are unquestionably the best of any distinct breed for the farmer, being good foragers, and far from troublesome or mischievous about the steading. London and other large towns are supplied by large numbers of chickens and capons of this breed. The offal is small in comparison to the flesh, which in flavour is justly held as excellent. The shape, size, and beauty of plumage, together with its hatching properties, recommend the Dorking to the attention of every poultry-keeper. Of three distinct colours, red, white, and gray, the last-named is the best and most common. Even of it there are two varieties, the 'silver' and the coloured. It is only in colour, however, that these birds differ.

The Poland (Polish or Paduan) fowl is much valued by breeders, but is not often found perfectly pure in Britain. The species was imported principally from Holland; and when unmixed, was uniformly of a black colour, with a white crest or tuft of feathers, instead of a comb, on the heads of both cock and hen. They are reared in immense numbers in France and Egypt, the eggs being hatched in the latter country artificially. Their form is plump and deep, and the legs of the best sorts not too long. They are splendid layers, but are not good hatchers, from a natural disinclination to sit on eggs.

The Spanish fowl is of considerable size, and lays large eggs. It is of the Polish family, and is almost uniformly marked by a black body, dark legs, white sides of head, and large red combs. This variety ranks as one of the standing breeds in this country, mainly on account of its laying properties. Spanish fowls are beautiful stately birds, though not so good hatchers, nor so much prized on the table, as some other breeds.

The Malay fowl is described as handsome, but it is not much introduced into this country, nor is it likely to be, because of its pugnacious habits.

Probably the most beautiful of all the breeds is the Hamburg, of which there are at least five varieties—namely, golden-pencilled, silver-pencilled, golden-spangled, silver-spangled, and black.

The Hamburg fowl, from its beauty of plumage and tendency to frequent laying, has gradually become a great favourite amongst poultry-fanciers, and is pretty widely distributed, not only throughout the British Islands, but over the continent of Europe and the United States. Its symmetry is surpassed, perhaps, only by that of the game fowls, and it is unrivalled as to the number of eggs it produces. Naturally somewhat wild, the cocks are keen fighters.

In reference to the Hamburgs, Mr Edward Lowe of Combesford, a successful prize-taker, says: 'I have never been able to ascertain the *exact* number of eggs that one hen will lay in a year, but I know that some of them have produced more than 200. Under very favourable circumstances, a single hen might produce at least 250; but I should say about 170 would be the average for any given number of fowls. True-bred Hamburgs never shew any inclination to sit; and this, which is considered by many one of their best qualities, might prove a serious difficulty to many poultry-keepers who are not able to keep another sort of hens as incubators.'

The golden-pencilled variety seems the greatest favourite with many. The black variety is said to be the most profitable, though the least beautiful of the five different sorts.

The Cochin-China fowl, upon which such sums have been expended, created a great sensation amongst all classes of breeders. The great mania was in 1852, when it was not uncommon to hear of £10, £20, or even £50 and upwards, being demanded for a good cock and hen; but latterly that extravagant mania has, like many others, in a great measure ceased; and the market value of the bird is now such as to place it within the range of the humbler classes of poultry-keepers. The plumage is gay in colour, and soft and yielding to the touch; in size and weight, it surpasses every other variety; the comb is of moderate size, and notched, and the wattles double; the head is small and narrow, the legs of medium length, and covered with feathers to the toes. It may be said to be all body, and no tail or wings, those appendages being almost wanting; hence the Cochin-China is by no means so graceful an ornament to the poultry-yard as the Hamburg or Dorking varieties. Nor is it so healthy and hardy as some other descriptions of birds. Where, however, proper attention can be paid to them, the Cochin-Chinas are profitable birds. The hens are excellent layers and good sitters, and their fecundity is remarkable.

The Brahmaputra fowl is believed by many to be closely related to the Cochin-China, being very like it in shape and size. The comb, however, of the Brahma fowl is different from that of the Cochin, and so are the bird's habits. Mr Mollison, factor, Dochfour, Inverness, who has recently issued an able treatise on Poultry, more particularly the farmer's fowl, thus describes the Brahma: 'The comb of a Brahma cock has the appearance of three small combs, that in the centre being the highest. The Brahma hen is an excellent layer, and lays freely in winter, which enhances her value. A Brahma hen, if fairly fed, rarely sits until she has laid forty to forty-five eggs, and that generally in about fifty days.' Brahma cocks have been known to weigh from fourteen to sixteen pounds. This breed, which comes very early to maturity, is very suitable for those who have of necessity a confined poultry-yard.

The Bantam fowl is a perfect parcel of symmetry, conceit, and pugnacity. It is well known for its diminutive size, courageous habits, and great activity. Originally a native of India, it should have a rose comb, a full tail, and a lively carriage, and should not weigh above one pound. The chief varieties are gold and silver laced, white, and black. The nankeen-coloured and black are said to be most prized. If well fed, the bantam hen will lay well even in winter, and considering the size of the animal, the eggs are astonishingly large, and contain a great proportion of yolk. The flesh of this tidy little bird is delicious. Mr Dickson thus truly writes of the bantam: 'It is a beautiful example of a great soul in a little body. It is the most pugnacious of its whole tribe. It will drive to a respectful distance great dunghill cocks five times its weight. It is more jealous, irascible, and domineering, in proportion to its size, than the thorough-bred game-cock himself. Its combativeness, too, is manifested at a very early period. The black bantam, in his appearance, is a pleasing little fellow. He should have a full rose comb, clean and sinewy legs, glossy plumage, with almost metallic lustre, of a different tint to the glancing green of the Spanish fowl, arched and flowing tail, waggish impudent eye, self-satisfied air and gait. The hen is of a duller jetty black, is less knowing in her manner, and, I think, in every way of inferior capacity.'

The Houdan fowl, a great favourite in France, is gradually growing in numbers and popularity in Britain. It is a portly bird, resembling a little the Dorking, having the fifth toe, short legs, a comb almost divided into two. The cock has very long wattles. Its head is surmounted by a bunch of small fine feathers, which tend almost to blind the fowl. The hens are excellent layers, and the breed altogether is reputedly hardy.

The Crevecœur, also a French fowl, is being introduced into this country, and is characterised by a crest on the top of its head similar to the Houdan. The cock has long pendent wattles. The body of it, on account of the exceedingly short legs, appears nearer the ground than does that of almost any other species of the domesticated fowl. It is a good table-fowl, and the hen is a fair layer.

Another French fowl of comparatively recent introduction into Britain is La Flèche, which is a large black bird, not so stylish or rich in plumage as the Spanish, but larger in size, and stands higher. The face is white, and the wattles long. The hen is a good layer.

Hen-houses.

The hen-houses in this country have been by far too long of an inadequate, uncomfortable description. Much improvement has in comparatively recent years been effected in this important respect, but throughout a considerable breadth of the inland and rural districts, there are still, unfortunately, many miserably constructed hen-houses.

Until proper housing accommodation is provided, the sort of prejudice that exists with many

farmers against poultry, as being more destructive than profitable, is not likely to be removed. Of course, when the fowls have a cold, damp, imperfectly thatched, irregularly cleaned, ill-lighted habitation, and are otherwise inadequately attended to, they do become more a pest than a pleasure or profit, for they stray away, roosting in the byres, the stable, or the cart-sheds, and thus court the hostility alike of the farmer, cattleman, and horseman. Eggs, too, are dropped in nearly every conceivable place about the steading, and often not discovered till either rotten or broken. In this carelessly kept state, the mischievous propensities of the fowls are fully demonstrated. The writer could point to several farm-steadings where two or three score of fowls are kept, and not a hen-house to be seen—the birds roosting in this apartment to-night, and the other to-morrow night, and so on. During the day, they cater the most of their food on the grass and other fields, and about the steadings, often doing mischief. Treated in this manner, eggs are comparatively few, the birds are not so big nor so valuable in any respect. It is customary—though now to a much smaller extent than it once was—with Highland crofters and farmers to erect a small turf-hut about a mile from the homestead, on a moor or mountain side, and keep the poultry there during harvest, in order to prevent them entering the corn-fields, in which they do considerable damage at that season. Throughout this period of exile, so to speak, the birds are generally stintedly fed, and if the weather is cold, they suffer from exposure. In short, this system would occasionally afford scope for the operations of the Society for the Prevention of Cruelty to Animals. That poultry can be kept with a profit, seems undoubted, if the animals are properly treated. One of the primary, if not the principal means to this profitable end, however, is unmistakably good house-accommodation; and though hen-houses are rapidly improving, there is still much to accomplish in this direction.

The results, to which reference shall be afterwards made, would amply reward any additional trouble and expense involved by a more speedy substitution of comfortably erected hen-houses for the pitiful shielings already described as still existing, though happily on the wane. Without cleanliness and warmth in the hen-house, any amount of attention otherwise will not realise nearly the maximum profit. Every poultry-house should be well cleaned at least once a week, to free it from vermin, hurtful odours, &c. At farms and other places where a great stock of poultry is kept, a proper house, with separate accommodation for the different varieties, should be provided. The hen-house should have at least four compartments and a court-yard. The annexed sketch exhibits the requisite accommodation: *a a*, the court-yard; *b b*, for ducks and geese, the apartment for which is at *c*, with laying and hatching nests, *d*; *g*, the roosting-house for hens and turkeys; *e*, the hatching-house; and *f*, the apartment for laying. Each compartment should be provided with a shutter-door, which must be closed every night. If, through inattention, the hen-house

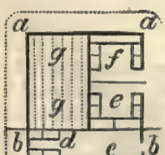


Fig. 4.

should become *tainted*, the health of its inmates will be greatly endangered. A new site should be chosen, and another house erected, or fumigation resorted to. Care should be taken in the selection of the site to have it on a dry, sloping piece of ground, with a southern exposure, and well sheltered. Ventilation, light, and warmth ought never to be lost sight of in the construction of these houses. Into the more modern poultry-houses, steam heating-pipes have been introduced, which admit of the hatching of chickens early in spring very successfully, and keep the hens in laying trim over the most of winter. The enhanced price of eggs in winter, and the advantage of getting chickens early into the market, are declared by those who have experience to repay fully the cost of the artificial heating. The roof should be quite weather-tight, as poultry never thrive when exposed either to cold draughts or moisture. The interior should be at least six feet high, for the convenience of the person who cleans the house. The perches should be placed so that the fowls on the top row may not be immediately above those on the second, and so on; a hen-ladder must be provided, but this, like the roosts, should not be too high, as fowls are apt to injure themselves by flying from lofty perches. The floors should be strewn with sand or dry earth, and swept clean every day: those sweepings will be found most useful for the

Fig. 5.—Poultry-pen.

garden. The door should be kept open in fine weather for the sake of ventilation; it should also have a hole at the bottom, with a sliding panel.

The laying-boxes require frequent washing with hot lime-water inside, to free them from vermin, which greatly torment the sitting hens. For the same purpose, poultry should always have a heap of dry sand or fine ashes laid under some covered place or shady tree, near the yard, to dust themselves in, this being their resource for getting rid of the vermin with which they are annoyed. The poultry-yard should contain some lime in a dry mortar state, of which the fowls eat a little. It is necessary for the formation of the egg-shell. If possible, also, the yard should include a patch of grassland.

Fig. 5 represents a section of a range of pens for the exhibition of poultry of the various kinds, constructed on the principle of shewing all the animals of the same species under the same light, and the same conditions generally. The suite of ground-compartments is adapted for geese, ducks, turkeys, rabbits; the next stage is for gallinaceous fowls of the various breeds; and the upper stage is provided with a perch for pigeons, and might also be used for dwarf-fowls. It is a French design.

Feeding.

Most persons are doubtless aware that fowls swallow food without mastication. That process is rendered unnecessary by the provision of a *crop*, an organ which is somewhat similar to the first stomach of the cow, and in which the food from the gullet is macerated, and partly dissolved by secreted fluids. From the crop, the food passes downwards into a second small cavity, where it is partly acted on by a digestive juice; and, finally, it is transferred to the gizzard, or last stomach, which is furnished with muscular and cartilaginous linings of very great strength. In the gizzard, the partially softened food is triturated, and converted into a thin paste, fit to be received into the chyle-gut, and finally absorbed into the circulation. Such is the power of the gizzard in almost all kinds of poultry, that hollow globes of glass are reduced in it to fine powder in a few hours. The most rough and jagged bodies do no injury to the coats of the gizzard. Spallanzani even introduced a ball of lead, with twelve strong needles so fixed in it that their points projected a fourth of an inch from the surface, and the result was, that all the needles, with the exception of one or two, were ground down in a short time to the surface of the ball, while those left were reduced to mere stumps. To add to the triturating powers of the gizzard, fowls are gifted with the faculty of swallowing gravel with their food.

Fowls, when left to roam at large, pick up all sorts of seeds, grains, worms, larvæ of insects, or any other edible substances they can discover, either on the surface of the ground or by scraping. They also pick a little grass as a stomachic. The more that hens can be allowed to run about to gather their food, provided always their housing is good and supplementary feeding judicious, the better for their health and for the pockets of the owner. It has been demonstrated that some of the more fashionable breeds will turn out remunerative even when kept in comparative confinement and fed artificially; but this process requires the strictest attention to the character of the diet, and considerable skill in the produce of poultry.

Going at large over a farm, the fowls at certain seasons damage some kinds of crops, and, in consequence, the number of birds fed in large yards regularly, in comparative confinement, especially about the larger farms, is gradually increasing.

In a state of domestication, the hard food of which fowls seem most fond are peas, barley, oats, &c.; and besides a proportion of these, they may be given crumbs of bread, lumps of boiled potatoes, not too cold, cabbage, turnips chopped small, &c. They are much pleased to pick a bone; the pickings warm them, and excite their laying propensities. If they can be supplied with caterpillars, worms, or maggots, the same end will be served. Any species of animal food, however, should be administered sparingly; and the staple articles of diet must always be of a vegetable nature. They should be fed three times a day. When wanted for the table, the quantity of food may be increased, and be more substantial; they should also be kept more within the coop, and as quiet as possible. A fortnight's feeding in this way will bring a fowl of a good breed up to a plump condition. The flavour of the chicken on the table will be enriched by feeding for ten days or so with oat and barley meal, and with a little sweet milk to drink. To be valuable in the nest, or on the table, none of these fashionably bred, early matured fowls should be kept longer than two years, though many, indeed most, of the old barn-door birds are kept with advantage longer.

The duties of hen-wife should be discharged constantly by one and the same person, as the voice and presence of a stranger scare the fowls, and disturb the operations of the hen-house. The profits of the poultry department at many a rural holding are considerably lessened by a breach of the above rule, by intrusting the duties of the hen-wife to perhaps, in the case of a large growing family, half-a-dozen different individuals in one day, and occasionally to mere urchins.

Laying.

The ordinary productiveness of the hen is truly astonishing, as it usually lays, in the course of a year, 200 eggs, provided it has not unnatural confinement, is well fed, and has a plentiful supply of water. Instances have been known of hens laying 300 in a year. This is a singular provision in nature, and it would appear to have been intended peculiarly for the use of man, as the hen usually incubates only once in a year, or at most twice. Few hens are capable of hatching more than from twelve to fifteen eggs; so that, allowing they were all to sit twice a year, and bring out fifteen at a time, there would still be at least 170 spare eggs for the use of man. It is therefore evident that, in situations where hens have comparative freedom, are well fed, and otherwise carefully attended, they must prove very profitable; for, supposing that the eggs of one fowl during the year were sold, without any of them being hatched, they would bring, if near a large city, on an average, 1s. per dozen, or about 18s.; and the hen herself would be worth 2s. at least. As the number of eggs which are annually brought out by a hen bear no proportion to the number which she lays, schemes—to be subsequently noticed—have been imagined to hatch all the eggs of a hen, and thus turn her produce to the greatest

advantage; so that, in place of twelve or fourteen chickens, upwards of 200 may be raised from the annual produce of a single fowl.

Hens will lay eggs which have received no impregnation, but from these, as a matter of course, no hatching can take place; they are equally good, however, for eating. When the chief object is to breed chickens, a cock should be allowed to walk with ten or twelve hens; but when eggs are principally required, the number of hens may be from fifteen to twenty. Endeavour to procure a cock of a good breed, not game, and let him be in his prime, which is at eighteen months to two years old. Cocks will last two years, after which they lose their liveliness of colours, and become languid, inactive, and mere consumers of food. It is fit, therefore, that younger cocks should then take their place in the poultry-yard. Crowing hens should be rejected, as worthless layers.

If left to themselves, hens produce not more than two broods a year. Early spring, and, after a cessation, the end of summer, are the two seasons in which they begin naturally to lay. In the depth of winter, under ordinary circumstances, hens very rarely lay eggs, though, by artificial means, as already explained, they can be made to do so. If the temperature of the place where they are kept be raised by a stove, or otherwise, they will produce eggs. The fowls of the Irish peasantry, and of some of the Highland Scotch cottars, which are usually kept in the cabins of the owners, lay often in winter, in consequence of the warmth of their quarters. The fecundity of hens varies considerably. Some lay but once in three days, others every second day, and others every day. In order to induce laying, each hen should have its own nest, or nearly so, made with soft straw or heather, and furnished with a piece of chalk as a decoy or *nest-egg*. The signs which indicate when a hen is about to lay are well known. She cackles frequently, walks restlessly about, and shews a brighter redness in her comb and wattles. After the process of laying is over, she utters a series of loud and peculiar notes, to which the other fowls usually respond. Shortly after the egg is laid, it should be removed, for the heat of the hen soon corrupts it. When the eggs are taken away by the poultry-keeper, they should immediately be laid in a cool and dry place. If allowed to absorb damp, they soon spoil; indeed, one drop of water upon the shell quickly taints the whole egg. When the hens lay in a secret corner or covert, the keeper may sometimes discover it by placing a few grains of salt in the oviduct, which hurries on the process of laying, and causes the animal to retire to the spot anew.

Various methods have been tried to prevent the absorption of air through the shell, and preserve the freshness of the eggs. Some keep them secluded from the air in bran, rye, or ashes, which may do very well where the eggs are to be kept in this way till eaten, but is utterly useless if quantities of them have to be sent to market. If the eggs are gently rubbed with fresh butter when newly laid, they will keep perfectly, and be as fresh for breakfast three months afterwards, as when newly dropped. Mr Mollison says he has found the following, with less trouble, to answer the purpose even better, namely: 'Place them in a water-tight cask, the small end of the egg down, and keep the whole always covered with a strong solution of lime-water.'

In consequence mainly of the insufficient hen-house accommodation, and the imperfect attention to the fowls otherwise, the egg-supply of this country is far from fully developed. Those who have given their attention to the subject, and had opportunities of observing how much the laying faculties of the hens, in many rural districts, are impaired by imperfect treatment, and how many of the eggs that are dropped, through bad nesting arrangements, are lost to the food-consumer, will not be slow to admit, that, with proper management, extended over all the poultry departments, the annual import of eggs, amounting to about 500,000,000, could be, if not entirely avoided, at least immensely reduced.

Hatching.

When eggs are to be hatched, it is necessary to pay attention to the choice of proper ones for the purpose. Those too much pointed at the ends should not be selected. The eggs must also be fresh; from the time they are laid, they should lie aside in a cool place. It is said to be possible to ascertain, from the appearance of the egg, whether the forthcoming progeny is to be male or female; but this is, we fear, a delusion. When eggs are left to be brought forth by the hen, a certain number are placed under her in the nest, when she is in the full inclination to sit. From nine to fourteen eggs are placed, according to the extent of the breast and wings; and the time required for hatching is about twenty-one days. Sometimes a hen will desert her eggs, a circumstance which may occasionally be traced to an uncomfortable condition of the skin, caused by vermin or want of cleanliness; and this affords a strong reason for keeping the hen-house clean, and giving the animals the means of purifying their feathers. Occasionally the hen is vicious, or, in short, a bad sitter, and experience in pitching on the best hatching-hen is the only remedy. Sometimes a hen will break her eggs with her feet; and in such cases the broken eggs must be removed as soon as observed, otherwise she may eat them, and from that be tempted to break and eat the sound ones, and thus spoil the whole.

It has generally been found that hens which are the best layers are the worst sitters. Those best adapted have short legs, a broad body, large wings, well furnished with feathers, their nails and spurs not too long or sharp. The desire to sit is made known by a particular sort of clucking note, or, as it is termed in Scotland, *clocking;* and a feverish state ensues, in which the natural heat of the hen's body is very much increased. The inclination, or, as physiologists term it, the *storge*, soon becomes a strong and ungovernable passion. The hen flutters about, hangs her wings, bristles up her feathers, searches everywhere for eggs to sit upon; and if she finds any, whether laid by herself or others, she immediately seats herself upon them, and continues the incubation.

With a proper provision of food at hand, warmth, quiet, and dryness, a good hatching-hen will give little trouble, and in due time the brood will come forth; one or two eggs may perhaps remain unhatched or addled, but their loss is of little consequence. As soon as the hen hears the

chirp of her young, she has a tendency to walk off with them, leaving the unhatched eggs to their fate. It is therefore advisable to watch the birth of the chicks, and to remove each as soon as it becomes dry, which may be in a few hours afterwards. By this means the hen will sit to hatch the whole; yet she should not be wearied by too long sitting. If all the eggs are not hatched at the end of twelve or fifteen hours after the first chick makes its appearance, in all probability they are addled, and may be abandoned. It is a good arrangement to 'set' two or more hens at the same time, so that in the event of only some half-dozen chickens from each nest, two broods can be taken charge of by one hen.

The chicks must be kept warm the first day or two. The food given to the young chicks should be split grits, which they require no teaching to pick up; afterwards, the ordinary food of the poultry-yard, or what the mother discovers for their use, is sufficient. Some give the yolks of hard-boiled eggs or curd, when a nourishing diet seems advisable. The extreme solicitude of the hen for her young, or the brood which may be imposed upon her, is well known. She leads them about in quest of food, defends them by violent gesticulations and the weapons which nature has given her, calls them around her by a peculiar low clucking cry, and gathers them carefully under her wings, to shelter them from danger, or to keep them warm at night. This maternal care is bestowed as long as the chickens require her assistance; as soon as they can shift for themselves, the mutual attachment ceases, and all knowledge of each other is very speedily lost. The young now go to roost, and the mother again begins to lay. Young hens, usually called pullets, begin to lay early in the spring after they are hatched. As heat is all that is necessary to develop the chick in the egg, eggs may be hatched artificially, without the intervention of the hen. The art has long been practised in Egypt, and has since been adopted in many other quarters, but with indifferent success. In the variable and moist climate of Great Britain, at least, there is little chance of Eccaleobions, or Patent Incubators, ever superseding, to any great extent, the office of the brooding-hen.

Capons.

By removing the reproductive and oviparous organs from the male and hen chickens respectively, a great change is produced in them as regards voice and habits, and they can be made remarkably fat for the table. Fowls thus operated on are called capons. They are chiefly reared in Sussex, Essex, and one or two other counties around London, and can be trained to watch chickens, hatch eggs, and do many useful offices of the poultry-yard. Upon the whole, however, the special benefit derived from rearing capons does not counterbalance the trouble which they give, and the danger of the primary operation; and the consequence is that the number of capons is decreasing.

Diseases.

Though on the whole fowls are naturally healthy, chickens are liable to various diseases, demanding attention from the poultry-keeper. The *pip* is the most common; it consists of a catarrhal thickening of the membrane of the tongue, causing a dangerous and obvious obstruction to respiration. It may be cured in most cases by throwing the fowl on its back, holding open the beak, and scraping or peeling off the membrane with a needle or the nail. The part may be wetted with salt or vinegar afterwards, and a little fresh butter pushed over the throat. *Thirst* sometimes attacks fowls like a fever, and often arises simply from dry food, though more frequently symptomatic of indigestion or some internal and deep-seated derangement. Careful attention to diet is the first and great point in all such cases. If *constipation* appear to be present, bread soaked in warm milk, boiled carrots or cabbages, earthworms, chopped suet, or hot potatoes with dripping, will be found useful. A clyster of sweet oil should be tried in severe cases. Where a tonic seems to be required, a little iron rust may be mixed with the food, and will generally relieve atrophy or loss of flesh. Where diarrhœa or scouring is observed, iron or alum may be given in small quantities. Where general fever has been observed in fowls, the use of a little nitre has been found very advantageous. Saffron is another remedy very often employed in relieving the symptoms of sickness in fowls.

TURKEYS.

The turkey, like the common fowl, has been included by naturalists in the *Gallinaceous* family of birds, and possesses the main characteristics common to the whole. It is a native of the woods of North America, and is certainly one of the most valuable fowls which have been naturalised in this country, but is very difficult to rear. The turkey-hen lays from fifteen to twenty eggs, and then sits upon them. She will bring out two broods in a year. The eggs are of a pale yellowish-white colour, finely streaked and spotted with reddish-yellow. They are a most delicious food, more delicate in flavour than the egg of the common hen. There is an interval of a day between the laying of each egg. It is said that the first two eggs which she lays are unfruitful. A turkey-hen can seldom hatch more than from sixteen to eighteen eggs. The time of incubation varies from twenty-seven to twenty-eight days, at which time the young begin to pierce their shelly prison, and emerge from it. The varieties most common in this country are the Norfolk and the Cambridge turkeys. The former is entirely black, and if not quite so heavy as the Cambridge, is second to none in beauty and symmetry.

General Management.

The turkey-chick is the most delicate of the poultry tribe to rear, and the utmost care is required to bring it past the tender age. If the poults get the slightest damp or frost, the chances are they will either die or be spoiled about the legs and joints. For the rearing of these valuable birds, special accommodation is absolutely necessary, and the floor should be laid with wood. Dampness from above or below, as well as strong sunshine, they must be protected from for some weeks. Should they accidentally get wet, they may be carefully dried with a towel, placed near a fire for some time, and fed on bread mixed with a small quantity of ground pepper or

ginger. Dry and sandy situations are most congenial for breeding turkeys, and especially elevated situations where large woods are contiguous. A single male turkey is sufficient for twelve or sixteen females, although the former number is probably the safest, to prevent sterility in the eggs, which is frequently the case with those of turkeys. Eggs should never be intrusted to the care of a female until she is at least two years of age, and hens may be kept for the purpose of incubation till they reach their tenth year. The largest and strongest hens should always be kept for this purpose. During the time the hen is sitting, it becomes necessary to place food near her; otherwise, from her assiduity, she may be starved to death, as turkey-hens incline to close sitting during the whole time of incubation.

When farmers rear turkeys in large numbers, which, on account of their extreme delicacy when young, is comparatively rare, it is seldom they indulge the hen by allowing her to sit as soon as she has done laying, but keep the eggs from her until all the other hens have ceased to lay, as it is of consequence that they should all be hatched about one time. When hens are unhappy during this interval, they may be indulged with common hens' eggs. When they have all ceased to lay, each of them is provided with a nest ranged close to the wall, in a barn or other convenient place, and each is supplied with from sixteen to twenty of her own eggs. On the twenty-sixth day, the person who is intrusted with the management of the birds examines all the eggs, and removes those that are addled; feeds the hens, and does not again disturb them till the poults have emerged from their shells, and have become perfectly dry, by the heat of the parent bird. To be subjected to cold at this time would certainly kill them. When the young birds are thoroughly dried, two of the broods are joined together, and the care of them intrusted to a single hen. Some people prefer hatching turkeys by means of common hens, but, of course, fewer eggs must be given.

The chicks should get little food for twenty-four hours after they leave the egg. Their first food should be hard-boiled eggs finely chopped, and mixed with crumbs of bread. Curd is also an excellent food for them. When they are about a week old, boiled peas and minced scallions are given to them. If eggs are continued, the shells should be minced down with their food, to assist digestion, or some very coarse sand or minute pebbles. They should be fed often at first, and afterwards not less than thrice a day. As they get older, a mixture of lettuce-milk will be found beneficial, together with minced nettles. Barley boiled in milk is another excellent food at this period, and then oats boiled in milk. In short, the constitution of young turkeys requires at all ages every kind of stimulating food. When about three weeks old, their meat should consist of a mixture of minced lettuce, nettles, curdled milk, hard-boiled yolks of eggs, bran, and dried chamomile; but when all these cannot be readily obtained, part of them must be used. Fennel and wild endive, with all plants which are of a tonic character, may be safely given to them. After the age of a month, the poults may be allowed to range the plantation or the field with the guardian bird, but even until double that age, care is necessary, as they are still susceptible of fatal injury from cold and wet. Grass, worms, all kinds of insects and snails, are their favourite food, and nature dictates to them such vegetables as are conducive to their general health. As their feet are at first very tender, and subject to inflammation from the pricking of nettles and thistles, they ought to be rubbed with spirits, which has the effect of hardening the skin, and fortifying them against these plants.

The glandulous fleshy parts and barbles of their heads begin to develop when they are from six weeks to two months old. This is a critical period with the poults, and unusual care must be bestowed on them, as they now become weak, and often sickly. A little brine mixed with their food will be found very beneficial, or spirits much diluted with water. A paste made of fennel, pepper, hemp-seed, and parsley, has been found an excellent remedy when afflicted with an inflammation in the wattles, to which they are liable when growing. When the inflammation becomes very great, recourse is often had to bleeding in the axillary vein, which frequently has the effect of recovering them.

Soon after the turkey-poults have acquired their first feathers, they are liable to a disease which is very fatal to them, if not attended to. This distemper produces great debility, and the birds appear languid and drooping, and almost totally neglect their food. Their tail and wing feathers assume a whitish appearance, and their plumage has a bristled aspect. This is occasioned by a disease in two or three of the rump-feathers. On examination, the tubes of these will be found filled with blood. The only remedy for this disease is to pluck the feathers out, when the bird will speedily acquire its wonted health and spirits.

In the preparation of turkeys for the table, various methods are resorted to. Some feed them on barley-meal mixed with skim-milk, and confine them to a coop during this time; others merely confine them to a house; while a third class allow them to run quite at liberty. The last practice is believed to be by far the best. Care should, however, be taken to feed them abundantly before they are allowed to range about in the morning, and a meal should also be prepared for them at mid-day, to which they will generally repair homewards of their own accord. They should be fed at night, before roosting, with oatmeal and skim-milk; and a day or two previous to their being killed, they should get oats exclusively. A change of food will be found beneficial. Boiled carrots and Swedish turnips, or potatoes mixed with a little barley or oat meal, will be greedily taken by them. A cruel method is practised, chiefly on the continent, to render turkeys very fat, which is termed cramming. This is done by forming a paste of crumbs of bread, flour, minced suet, and sweet-milk, or even cream, into small balls about the bulk of a marble, which is passed over the throat after full voluntary meals. Some turkey-cocks, well fed, have reached the weight of 35 lbs. The aged turkey, for all its tenderness of youth, can stand more cold than any other domestic fowl. It is not very uncommon to find turkeys, especially cocks, roosting at some farms on the branches of trees in the open air, during winter, in all sorts of weather, with apparent comfort.

PEA-FOWL.

The peacock, also one of the Gallinaceous tribe of birds, came originally, it is said, from India, and was well known to the ancient Greeks and Romans, who introduced it into their mythology. The great beauty of its tail, so ample in extent, and so rich in colours, rendered it indeed not unworthy of such preferment.

One peacock is usually kept with three or four hens. The female is extremely fastidious about a spot to lay in, and generally leaves any artificial nest for the grass of some neighbouring coppice, where she lays under the branches of a shrub, in a well-concealed situation. One reason for this is the propensity of the cock to break the eggs if he discovers them. When the eggs of the peahen are gathered in sufficient numbers, whether from a natural or artificial nest, it is a common practice to place them under a common hen, which hatches them in thirty days, and makes an excellent stepmother to the young chicks. These are very tender at first, but soon grow vigorous, even in a chilly climate. Barley-meal paste, mixed with cheese or curd prepared from milk, with alum, ants' eggs, meal-worms, and hard-boiled egg, are among the common articles of diet given to the young. The grown-up pea-fowl feeds on boiled barley or other common grains, and is a dangerous visitor of corn or wheat fields and gardens. On the other hand, they are voraciously fond of such creatures as frogs, lizards, and the like, and keep grounds clear of such annoyances. In moulting-time, it is requisite to be more careful of these fowls than at other times, and to give them good grain, with a little honey and fresh water. Though the tongues and livers of peacocks were ranked among the dainties of the Roman epicures, the bird is rarely killed for table nowadays, and indeed is grown mostly for ornament. It always bears a high price, being one of the most beautiful of the feathered race, and an object on which the eye ever delights to dwell, though its screaming note by no means gives a corresponding pleasure to the ear.

THE GUINEA-FOWL.

This stranger is found native in Africa, as its name indicates, and it also exists in an indigenous state in South America. The Guinea-fowl (*Numidia meleagris*) is about the size of the common hen, and the male differs very little in appearance from the female. Three species exist in considerable numbers in Europe—namely, the crested, the mitred, and Egyptian varieties. A very beautiful sort is marked by a pure white tint of body, but the most familiar hues are dark-gray and black. The bird is less tame than other common poultry, and prefers to live in a half-wild condition in its native regions, perching and living on trees like undomesticated birds. It is a spirited creature, and will battle even with the turkey. Guinea-hens require great attention at the time of laying, making their nests by preference in corners of the woods. Their eggs are small, but much esteemed; and the common hen is usually made to rear their broods. In the market, guinea-fowls always bear a high price, both on account of their flesh, which is of a good quality, and because they form a very pretty variety of the poultry stock. Their food is grain, of the various kinds given to ordinary barn-door fowls, with which they assimilate closely in habits. On the whole, they may be said to be kept more from curiosity than for profit.

THE GOOSE.

The goose differs in many respects from the fowls already noticed, being aquatic in its habits. It is marked by a flat bill and webbed feet, characters also possessed by the duck and swan, which, in conjunction with the goose, may be held as forming a distinct family (*Anatidæ*) of the feathered aquatic tribes.

Our common tame goose is the wild species domesticated, known to naturalists by the name of the fen or stubble goose. Where people have a right of common, or live in the vicinity of marshy heaths, the breeding and rearing of geese will prove very profitable, for in such situations they are kept at a trifling expense; they are very hardy, and live to a great age. If properly kept, and fed regularly, although sparingly, they will lay upwards of 100 eggs yearly. If these are set under large hens, each having half-a-dozen, with the assistance of the goose herself, they may be nearly all hatched. For the first three or four days, the young must be kept warm and dry, and fed on barley-meal or oatmeal mixed with milk, if it is easily procured; if not, let these ingredients be mixed with water. They will begin to grow in about a week. For a week or two the goslings should not be turned out till late in the morning, and should always be taken in early in the evening. In Ireland, many of the tenantry depend largely on the breeding of these birds and turkeys to pay their rent; and with those who are industrious and favourably situated for rearing geese, they even do more in many cases. In Caithness, for instance, the cottars breed large numbers of geese, and dispose of them—or many of them—to the farmers, who have them herded in immense droves on the lea, and afterwards on the stubble land. They soon get quite fat, and not only pay the breeder well, but often the feeder better. Geese fatten more rapidly picking the stray grains left on the stubbles than under any other of the common modes of feeding them. Both the quantity and flavour of the flesh are materially improved on the stubble-land.

Although water is the natural element of geese, it is a curious fact that they feed much faster in situations remote from rivers and streams; still they must have abundance of fresh water to drink. To fatten geese, it is necessary to give them a little corn daily, with the addition of some raw Swedish turnips, carrots, mangold-wurzel leaves, lucern, tares, cabbage-leaves, and lettuces. They should not be allowed to run much at large when they are fattening, as they do not acquire flesh nearly so fast when allowed to take much exercise. The pen or inclosure in which they are kept should be of considerable size, and afford ample protection from the sun. There should be three troughs in the pen: one for dry oats, another for vegetables—which ought always to be cut down—and a third for clean water, of which they must always have a plentiful supply. It must be remembered that the riper the cabbages and lettuces with which they are supplied,

the better. In the fens of Lincolnshire, vast quantities of geese have long been kept, partly for their quills and feathers, and partly for their carcases. Geese breed in general only once a year, but if well kept, they sometimes hatch twice in a season. The best method for promoting this is to feed them with corn, barley, malt, fresh grains, and, as a stimulant, they should get a mixture of pollard and ale. During their sitting, each bird has a space allotted to it, in rows of wicker-pens placed one above another, and the goose-herd who has the care of them drives the whole flock to water thrice a day, and bringing them back to their habitation, places every bird in its own nest. One gander is generally put to five geese. The time of incubation varies from twenty-seven to thirty days. The goose begins to lay in March, but the time of the month depends upon the state of the atmosphere. When goslings are first allowed to go at large with their dam, every plant of hemlock which grows within the extent of their range should be pulled up, as they are very apt to eat it, and it generally proves fatal to them. Nightshade is also equally pernicious to them, and they have been known to be poisoned by cropping the sprigs of the yew-tree.

DUCKS.

Ducks are easily kept, particularly near ponds or streams of water. In such situations, even the poorest families may have half-a-dozen of them running about without the least inconvenience. In keeping them in a domestic state, one drake is usually put to half-a-dozen ducks. The ducks begin to lay in February; their time of laying being either at night or early in the morning. They are extremely apt to deposit their eggs in some sequestered spot, and to conceal them with leaves or straw. From eleven to fifteen eggs is the number which a duck can properly cover. The time of incubation is about thirty-one days. The place where they incubate should be as quiet and retired as possible; and if they have liberty, they will give no trouble whatever in feeding, as the duck, when she feels the call of hunger, covers her eggs carefully up, and seeks food for herself, either by going to the streams or ditches in her neighbourhood, or, if such are not at hand, she will come to the cottage and intimate her wants by quacking. When the young are hatched, they should be left to the care of the duck, which will lead them forth in due time; and when she does so, prepare a coop for them, which should be placed on short grass, if the weather is mild; and if cold or stormy, they should be kept under cover. The future strength of the brood will depend much upon the care that is taken of them for the first three or four weeks after they have emerged from the shell. Ducklings will begin to wash themselves the first day after they are hatched, if they find water at hand; therefore, a flat dish filled with that element should be always within their reach. They need not be confined in the coop more than a fortnight or three weeks.

The first thing on which ducklings are fed is a mixture of barley, pease, or oat meal, and water. They may afterwards be fed on a mixture of buckwheat, and any of the above-named meals. The greatest attention must be paid to keeping their bed warm and dry; and with young ducks, a frequent change of straw is absolutely necessary, as their beds soon get dirty, wet, and fetid.

Ducks are not such attentive guardians of their young as hens, and therefore it is a common practice to place duck-eggs under a sitting hen, and leave her to hatch them as her own progeny. When the young ducks so hatched make their appearance, the hen does not appear aware of the imposition, but takes at once to her duties with a mother's fondness. The natural desire of the ducklings to plunge into water and swim away from the shore, vexes her, but she watches for their return, and does all in her power to provide the means of subsistence. She scrapes for them, which a duck would not; she shelters them under her dry and warm bosom and wings, and altogether makes a better nurse than their own proper parent, though it is somewhat cruel treatment to the hen.

A few ducks are profitable about almost every farm, and if there is an extensive grass or waste run near, a large number may be kept with advantage. Their food will cost very little, and they lay large good eggs, if not very many of them. The Aylesbury ducks are the prettiest, though the Rouen look best on the table.

In feeding ducks for use, pease and oat meal are to be preferred. It is said that barley-meal renders their flesh soft and insipid. Bruised oats should be given to them freely for some weeks before they are killed, which renders their flesh solid and well tasted; and the same general principles recommended in the feeding of geese should be kept in view. It has been found that the offal of butchers' shops feeds ducks quickly, and that this does not impair the flavour of their flesh. In very many instances, ducks are reared in situations where there are no pools of clean water for them to dabble in, and the poor animals are compelled to grub with their bills in all sorts of nauseous puddles, which, of course, makes their flesh rank and offensive. They should, in all cases, have a pool of clean water to swim in, and are best reared near a natural meadow, lake, or pond, where they can search for their appropriate food.

Geese and ducks should be kept separate from the rest of the poultry, if it can be conveniently done.

THE SWAN.

Swans are more commonly kept for ornament than for any other purpose. Some people do not like the flesh of swans, while others do. Young swans from the age of six weeks till three months are considered delicious on the table. They grow rapidly, and are not expensive or troublesome to rear, so that they might easily be produced with a profit, where circumstances were favourable. A little bread or grain laid on the edge of the water is all they care for in the way of hand-feeding. Its great size, snow-white plumage, and graceful form, render it a most attractive spectacle on the bosom of a pool or lake. It is a hardy, long-lived fowl, and associates in pairs. The food of the swan consists usually of seeds, roots, and plants, rendered succulent by water. When fed in a barn-yard, it seldom thrives, being more decidedly aquatic in its habits than ducks or geese. The eggs of the swan are not much in favour. She lays from six to eight eggs, and if these are not

removed as laid, the male bird may addle them by partially sitting. When the swan begins to sit on whatever eggs are substituted for those removed, her own ones should be replaced, and the others taken away.

PIGEONS.

Pigeons are among the most ornamental and useful appendages of a rural dwelling. If permitted to fly abroad to seek their food, little expense will be incurred for their keep, while the value of their young will be of some importance to cottagers. The pigeon has a great power of flight, and will go to a distance of many miles in quest of the means of subsistence; but wherever it may fly, it never fails to return home. The leading features of the district around its habitation appear to be impressed on its memory; and flying at a great height, and with a wonderful power of vision, it sees the well-remembered landmarks, and directs its path homeward. This habit of seeking for the place at which it was reared, makes it difficult to keep pigeons in any new home; the best plan of inducing them to settle in a new abode is to clip one wing, which prevents their flying, and keep them in a cot near the ground till they get accustomed to the place. Some persons keep their pigeons in the space between the garret and roof of their dwelling-house, with holes at which they go out and in; and this arrangement answers very well, for the animal's lodging must be dry and comfortable. A more regular plan is to furnish them with a properly constructed dove-cot, aloof from any building. The cot should consist of a substantial wooden box, with a sloping roof, and divided interiorly by partitions into as many cells as pairs are to be kept, for each pair requires a distinct cell. Each compartment should be twelve inches deep from front to back, and sixteen inches broad; the entrance-hole should not be opposite the centre of the cell, but at one side, so that the pigeons may build their nest a little out of sight. In front of each cell there should be a slip of wood, to rest and coo upon; but as different pairs incessantly quarrel about the right of walking on these slips, and are apt to fight for the possession of cells, it is best to separate the slips with upright partitions; and it would be an improvement to have two or three small cots instead of one large one. The cot, of whatever size or form, should be elevated on a wall facing the south-east, or otherwise placed at such a height as will be out of the reach of cats and other vermin. The cot should be painted white, as the pigeon is attracted by that colour. Gravel should be strewed on the ground in front of the dove-cot, the birds being fond of picking it; and a little straw or hay is necessary for the nests. Cleanliness is indispensable to the health of the birds, and a scouring out of the cot should therefore take place regularly.

In commencing to keep pigeons, a pair or two should be procured which have not flown, and they should be shut up for a time, and well fed. Their chief food is grain, and the kind which they prefer to all others is dried tares. Small horse-beans are another favourite article of diet, and very nutritious to them.

The house-dove, or common pigeon, as is well known, begins to breed about the age of nine months, and breeds every month. During breeding-time, they associate in pairs, and pay court to each other with their bills; the female lays two eggs, and the young ones that are produced are for the most part a male and female. When the eggs are laid, the female, in the space of fifteen days, not including the three days during which she is employed in laying, continues to hatch, relieved at intervals by the male. Kept with ordinary care, a pair will give to the breeder nine pair or so in a year, and will continue to do this for four years.

With regard to the best breeds of the common domesticated pigeon, it is difficult to give any useful instructions. They have been cultivated to a great extent, and many distinct varieties have been formed, but the differences rest chiefly in colours, and the special value of each lies in the taste of the *fancier*. The leading varieties of fancy-pigeons are known by the names of the English Pouter, the Dutch Cropper, the Horseman, the Unloper, the Dragoon, the Tumbler, the Leghorn and Spanish Runt, the Trumpeter, the Nun, the Fan-tail, the Capuchin, and the Burr. The last has a peculiarly short beak, and is remarkable for a ring of unfeathered flesh which surrounds a small sharp eye. The English pouter, depicted in the frontispiece, possesses the remarkable property of blowing out its breast or crop to such an extent that it rises to a level with its beak, and the bird appears to look over the top of an inflated bladder. The fan-tails are considered great beauties.

The training of pigeons as letter-carriers forms a lucrative employment in some countries. The instinct which has rendered the carrier-pigeon so serviceable, is the strong desire manifested by all pigeons to return to the place of their ordinary residence; and man has adopted various precautionary measures in order to make its return on particular occasions more certain. A male and female are usually kept together, and treated well; and one of these, when taken elsewhere, is supposed to have the greater inducement to come back. It is even considered necessary by some that the bird should have left eggs in the process of incubation, or unfledged young ones, at home, in order to make the return certain; but probably these are superfluous precautions. When the moment for employing it has arrived, the individual requiring its services writes a small billet upon thin paper, which is placed lengthwise under the wing, and fastened by a pin to one of the feathers, with some precautions to prevent the pin from pricking, and the paper from filling with air. On being released, the carrier ascends to a great height, takes one or two turns in the air, and then commences its forward career, at the rate of about forty miles an hour.

CAGE-BIRDS.

Prominent among the many birds usually domesticated in cages in Britain are canaries, siskins, goldfinches, bullfinches, larks, linnets, thrushes, blackbirds, starlings, and parrots. The only means by which these or any other species of birds can be reared and preserved in a healthy condition, is to accommodate each as far as possible with the food, space for exercise, and other conveniences which the animal would enjoy in a state of nature. The most difficult thing to

afford is space: where a room or aviary can be fitted up with all requisite accommodations—perches to resemble trees and branches, grass, moss, and other plants, patches of gravel or sand, secluded places for nests, a trough of clear water, &c.—the birds will thrive, breed, and be cheerful; but such accommodations can rarely be afforded.

Placed in this state of comparative confinement, no birds can possibly thrive unless great care is bestowed in furnishing them with food and fresh water daily, keeping their habitation very clean, and placing them in a cheerful situation in a parlour, where they can enjoy the light.

The food of cage-birds is very various. 1. Canaries, goldfinches, and siskins, live only on seeds; 2. quails, larks, chaffinches, and bullfinches, feed on both seeds and insects; 3. nightingales, redbreasts, thrushes, and blackbirds, take berries and insects. Rape-seed, hemp-seed, and poppy-seed are the favourite feed with the first class. To many enumerated in the other classes, cheese, crumbs of bread, barley-meal, cabbage, &c. are particularly palatable. Bechstein thus describes two kinds of paste extensively given to cage-birds:

'To make the first paste, take a white loaf which is well baked and stale, put it into fresh water, and leave it there until quite soaked through; then squeeze out the water, and pour boiled milk over the loaf, adding about two-thirds of barley-meal with the bran well sifted out, or, what is still better, wheat-meal; but as this is dearer, it may be done without.

'For the second paste, grate a carrot very nicely (this root may be kept a whole year if buried in sand); then soak a small white loaf in fresh water, press the water out, and put it and the grated carrot into an earthen pan, add two handfuls of barley or wheat meal, and mix the whole well together with a pestle.

'These pastes should be made fresh every morning, as they soon become sour, particularly the first, and consequently hurtful. For this purpose, I have a feeding-trough, round which there is room enough for half my birds. It is better to have it made of earthenware, stone or delf ware, rather than of wood, as being more easily cleaned, and not so likely to cause the food to become stale.'

Canaries are described as the chief pets of the parlour. Being originally from a warm climate, they are tender, and must be kept in rooms of an agreeable temperature; if exposed to cold either in rooms or the open air, they pine and die. In dry weather in summer, their cage should be hung in the open air, or at least in the sunshine. If the apartment is kept too hot, they will moult at an improper season, and this must be avoided. Only one male should be allowed in a cage. Females for breeding are the better for having a large cage, as it affords them space for exercise. The greatest care must be taken to clean the cage, of whatever dimensions, and to scatter a little fine sand on the bottom of it. Each should be provided with three cross-sticks as perches; a small glass-trough for water, fixed outside, at the extremity of one of the sticks. The water must be changed daily, or even more frequently.

Some persons, from mistaken kindness, offer pieces of rich cake and other inappropriate food to canaries, and the little creatures being fond of these things, do themselves a great injury by eating of them.

The breeding of canaries requires additional accommodations. The breeder must have a large cage, into which the pair of birds is put about the middle of April. At the upper part of the cage, at one end, boxes for the nests are placed, with holes to go out and in by; and in the centre of the cage, near a perch, a network bag is hung, filled with cotton, wool, moss, hair, and other soft materials, for the birds to use for their nests. The female alone builds: and in about ten days after pairing, she lays the first egg. She ordinarily lays six eggs—one every day; but each egg is to be taken away as laid, leaving an ivory one only; and when she has done laying, replace all the six. The period of incubation is thirteen days. When the young are hatched, finely minced egg and bread should be placed near the feeding-trough, to enable the parents to carry suitable food to their young. Canaries will mate with siskins, linnets, several of the finches, and other allied birds, producing in many instances highly esteemed mules. Similar treatment suits the siskin, of which there are several varieties, as the black, white, and speckled.

The skylark requires a roomy cage, at least eighteen inches long, nine wide, and fifteen high; the bottom should have a drawer, in which enough of river-sand should be kept for this scratching-bird to be able to roll and dust itself conveniently. It is also a good plan to have in a corner a little square of fresh turf, which is as beneficial as it is agreeable. The top of the cage must be of linen, since, from its tendency to rise for flight, it would run the risk of wounding its head against a covering of wood or iron wire, especially before it is well tamed. The vessels for food and drink must be outside, or a drawer for the food may be introduced in the side of the cage: sticks are not necessary, as the lark does not perch.

The starling, if well treated, soon becomes exceedingly familiar, and may be taught to whistle various airs, and pronounce words and short sentences with accuracy.

Parrots, paroquets, cockatoos, and macaws, all possess beautiful plumage of green, crimson, yellow, or grayish tints. They are chiefly from South America, and require the warmth of a dwelling-house to keep them alive in this country. All possess harsh voices, and would on that account be considered a positive nuisance by most persons, except for the oddity of their being able to repeat certain words. They are allowed a large cage, formed of strong wires, with thick round bars to perch upon, and a ring at top to swing from by their hooked beak. All the parts must be of tin, for they would soon peck wood to pieces.

The food offered to parrots, macaws, &c. is chiefly bread steeped in milk, nuts, or any other simple article. Care must be taken never to give them anything containing salt or pepper.

The cockatoo is generally esteemed as of milder temper than the parrot. For ornamental pets, paroquets—many of which are not much larger than the common house-sparrow—are generally preferred; and though not quite so showy in plumage as the macaws, lories, and cockatoos, yet their tints are often extremely beautiful, and they never become offensive by screaming, which is too often the case with their larger congeners.

THE HONEY-BEE.

THE subject of Bees has for many ages attracted the attention of mankind. The Sacred Writings, the most ancient of which we have any knowledge, shew in numerous places how strongly the fathers of the Jewish people had been impressed by the peculiarities in the natural history of the Bee; and we know that Aristotle and other philosophers of old Greece deemed the subject worthy of years of patient investigation. Virgil also, and many other Roman authors, dwelt on it with enthusiasm in their writings; while, in much later times, many distinguished cultivators of science have pursued the same track with ardour. The most zealous of these inquirers was Francis Huber (born at Geneva 1750, died 1831), who, though labouring under the deprivation of sight, by the aid of his wife formed a most valuable collection of observations on the habits of bees, and to whose work—as yet the best of its kind—we shall have frequent occasion to refer. Societies have been formed for the sole purpose of investigating this portion of natural history. On the present occasion, an attempt can only be made to cull from the most approved sources such details as may form a complete—although very concise—history of the Honey-bee, along with directions for the practical management of this most useful insect.

Bees are arranged by zoologists in the family of the *Apidæ* (*apis*, a bee), in the order *Hymenoptera* of the Insect class. (See ZOOLOGY.) The Social Bees form the principal division of the family, their type being the *Apis mellifica*, the common Honey-bee. To this species the observations to follow will have reference; but the description of it applies in all the most important particulars to the other honey-storing species of the Old World, the differences being very inconsiderable amongst those of them which, like it, have been made by man his property and the objects of his care. It is somewhat doubtful whether the common Bee is a native of Europe, or was originally introduced from the East. Another species, the Ligurian Bee (*Apis Ligustica*), is found in the south of Europe, and has recently been introduced into this country by some of our zealous bee-cultivators. The Hive-bee of Egypt is the Banded Bee (*Apis fasciata*). Besides these, there are other species, all very similar to them, as they are to each other, which are cultivated—if the expression may be used—in different parts of the East Indies and of Africa. The native wild bees of America do not belong to the genus *Apis*, but to a quite different group of the great family of the *Apidæ*, and their honey is remarkably liquid. The common honey-bee has, however, become completely naturalised in North America, and is to be found in the woods at great distances from the abodes of civilised men.

ANATOMY AND PHYSIOLOGY.

A hive of honey-bees contains three classes of inhabitants, the external characters of which differ considerably, while their uses and functions in the community are most obviously distinct. By far the most numerous class is that of the *workers*, or working-bees, formerly regarded as neuters in respect of sex, but now more properly considered as undeveloped females. The second class is composed of the males of the hive, termed the *drones*. There is usually but one perfect member of the third class present at a time in a hive, and this is the *queen*, or mother-bee, the sole perfect female of the community.

Workers.

The working honey-bee has a body about half an inch in length, blackish-brown in hue, and covered with close-set hairs, which are feather-shaped, and assist the creature materially in collecting the farina of flowers. The *head*, which is a flattened triangle in shape, is attached to the chest by a thin ligament; and the chest or *thorax*, which is of a spherical form, is united in a similar way to the *abdomen* (see No. 9). The abdomen is divided into six scaly rings, which shorten the body by slipping over one another to a certain extent. These three external divisions of the insect's body have all of them appendages of peculiar interest and utility. The head is provided with a double visual apparatus. In front are placed two *eyes*, consisting each of numerous hexagonal plates, studded with hairs, to ward off the dust or pollen of flowers; and three small eyes are also to be found on the very top of the head, intended, doubtless, to give vision upwards. The *antennæ*, however, which are two slender horns springing from betwixt the front eyes, and curving outwards from each side, most probably fulfil many of the purposes of vision in the dark interior of the hive. These instruments have each of them twelve articulations, and terminate in a knob, gifted with the most delicate sensitiveness. By the flexibility of the antennæ, the bee is enabled to feel any object in its way; and there can be little doubt that it is chiefly by means of these it builds its combs, feeds the young, fills the honey-cells, and performs the other operations of the hive. Bees also use these appendages for the recognition of one another.

The mouth of the bee is a very complex structure, and one wonderfully fitted for its duties. Its most important parts are the *mandibles*, the *tongue*, the *proboscis*, and *labial feelers*. The mandibles are merely the two sides of the upper jaw, split vertically, and movable to such a degree as to enable the insect to break down food betwixt them, to manipulate wax, and use them otherwise as serviceable tools. They are furnished with teeth at their ends, two in number. The tongue of the bee is extremely small. Many of the usual functions of a tongue are indeed performed by the proboscis, a long slender projection, composed of about forty cartilaginous rings, fringed with fine hairs. From the base of this, on

each side, rise the labial feelers, instruments also fringed or feathered interiorly; and outside of these are the lower jaws, similarly provided with hairs. When the feelers and jaws close in on the proboscis, they form a sheath or defence to it. Naturalists used to suppose the proboscis a tube; but they now know that it acts by rolling about and lapping up, by means of the fringes around it, everything to which it is applied. The gathered material is conveyed into the gullet at its base, whence it passes into the internal organs. When not in use, the whole can be so folded or coiled together as to be strongly protected.

To the trunk or thorax of the bee exteriorly are attached the muscles of the wings and legs. The wings consist of two pair of unequal size, which are hooked to one another, in order to act in concord and steady the movements in flying. The bee has three pair of legs, of which the anterior pair are the shortest, and the posterior the longest. All of them have articulations for the thigh, leg, and foot, with some minor joints in the latter part. The hind-legs are marked by a special and beautiful provision: a cup-like cavity on the basal joint, intended for the important purpose of receiving the kneaded pollen which the bee collects in its wanderings. The legs are all thickly studded with hairs, and more particularly the cavity mentioned, in which the materials require to be retained securely. Another provision of the bee's limbs consists in a pair of hooks attached to each foot, by means of which the animal suspends itself from the roof of the hive or any similar position. Beneath or behind the wings, the *spiracles*, or air-openings, are found, which admit air to the air-tubes, which, as in other insects, permeate the whole body, for the oxygenation of the circulating system. Bees carefully ventilate their hives. Oxygen is apparently as necessary to the vitality of the circulating fluids of insects as to those of warm-blooded animals. Huber completely proved both that respiration is essentially necessary to bees, and that the spiracles are the instruments by which it is effected. He found that they die in an exhausted receiver, and become asphyxiated when shut up in numbers in close bottles. They perish in water only if the spiracles are under the surface; and the use of these apertures is then made apparent by the bubbles which escape from them under water.

Besides these appendages and contents of the chest, that region is traversed by the *œsophagus*, or gullet, on its way to the digestive and other organs situated in the abdomen. These organs consist of the *honey-bag*, the *stomach*, the *wax-pockets*, and the *intestines*, with the *venom-bag* and *sting*. The honey-bag, sometimes called the first stomach, though digestion never takes place there, is an enlargement of the gullet into a pea-sized bag, pointed in front, with two pouches behind. In this receptacle is lodged the fluid and saccharine portion of the bee's gatherings, which, by the muscularity of the coats, can be regurgitated to fill the honey-cells of the hive. A short passage leads to the second or true stomach, which receives the food for the nourishment of the bee, and also the saccharine matter from which the wax is secreted. The small intestines receive the digested food from the stomach, and from them it appears to be absorbed for the purposes of nutrition. Wax, it was once thought, was pollen elaborated in the stomach, and ejected by the mouth; but it is now known to be entirely derived from the honey or saccharine matter consumed by the insect; and John Hunter discovered two small pouches in the lower part of the abdomen, from vessels on the surface of which it is secreted. After it has been accumulated for a time in these pouches, scales of it appear externally below one or other of the four medial rings of the abdomen, and are withdrawn by the bee itself or those around it. Close to the stomach is found the last important organ of the abdomen, the sting. Much beautiful mechanism is observed on a microscopic examination of this weapon, so powerful in comparison to its bulk. It consists of two long darts, adhering longitudinally, and strongly protected by one principal sheath. This sheath is supposed to be first thrust out in stinging; and its power to pierce may be conjectured from the fact that, when viewed through a glass which magnifies a fine needle-point to the breadth of a quarter of an inch, the extremity of the sheath ends so finely as to be invisible. The sheath once inserted, then the two still finer darts follow, and make a further puncture to receive the poison, which is conducted to the end of the sheath in a groove; and in order that the conjoined darts may not be withdrawn too soon, they have each nine or ten barbs at the point to retain them. The insect ejects the poison by means of a muscle encircling the bag at the base of the sting, in which bag the venom is secreted. The chemical composition of the poison has not been discovered, though it has so far the nature of an acid as to redden the vegetable blues. Altogether, Paley, in his *Natural Theology*, is fully justified in pointing to the defensive weapon of the bee as a wondrous union of mechanical and chemical perfection.

The manner in which the bee collects the food which forms the various secretions alluded to, is worthy of note. The hairs with which its body and feet are covered are the main instruments used. By means of the hairs on the feet, the insect usually begins its collection of the pollen in the corolla which it has entered, and after kneading the dust into balls, finally places it in the baskets of the hind-legs. But the creature is not content with the product of this process. Rolling its body round and round, it brushes off the pollen still more cleanly, gathers it into two heaps with its active brushes, and loads its baskets to the brim. Even afterwards, bees sometimes fly home like dusty millers, and brush their jackets when unloaded. The pollen is understood to be brought home by the working-bees as food for the young. The fluid secretions contained in the nectaries of flowers, and honey-dew, which is a deposition of certain aphides on plants, serve as other natural varieties of the bee's food. The insect is also at certain periods a liberal drinker of water.

The organs of vision of bees have been already mentioned. Inquirers have been staggered by seeming contradictions connected with the vision of the bee. After collecting its store of food, its first movement is to rise aloft in the air, and look for the site of its home. Having determined this in an instant, however distant the hive may be, it goes for the point with the directness of a cannon-ball, and usually alights at its own door,

though the whole country be crowded with hives. Yet, if the hive, or its door, has been shifted to a slight extent, the insect seems confused, and cannot find its way. The conclusion from this is, that the eyes of the bee have a lengthened focus, suiting them for the main purposes of its existence. But the consequent inability to determine accurately within short distances, has been compensated to the creature by the antennæ, which then become a highly serviceable resource. The sense of *taste* in bees has been the subject of much discussion. Huber was of opinion that it was the most imperfect of their senses, and they have been observed to resort to putrid marshes for water, even when they were not restricted in their choice. Xenophon found his men seriously injured by eating honey produced by bees which had fed on deleterious plants. But, on the other hand, it has been noticed that bees reject many substances, and prefer others, when a choice is allowed them; and it has been conjectured that they go to marshes purposely for the salt in their waters. Moreover, what renders the honey deleterious to man, may not be hurtful to bees. Honey formed from a particular flower in Jersey, was found unfit for use from its intoxicating qualities; yet the bees throve wonderfully upon it all the while. Their taste in selecting the richest flowers is likewise unquestionable. No doubt the sense of *smell* comes into operation on these occasions, as well as the sense of taste. Betwixt the influence and effects of the two, indeed, it is scarcely possible to discriminate. Even in the case of the human being, it is an established fact, that the powers commonly ascribed to the sense of taste are to a remarkable degree dependent on the sense of smell. If the eyes be bandaged, and the apertures of the nose well shut up, the most experienced judge will be at a loss to determine between any two kinds of ardent spirits, or other pungent substances. The most nauseous medicines, also, much as they may usually seem to affect the taste, will be found almost insipid if the site of the sense of smell be closed up while they are swallowed. In bees, the site of the two senses seems to be almost one and the same. Many experiments of Huber seem to prove that the sense of smell lies in the mouth, and that it is very acute. He found that they hate the odour of turpentine; yet on plugging up the mouth, they shewed no disgust when placed beside that liquid. He concealed honey at considerable distances, and they in a very short time detected the hidden treasure. The acuteness of their sense of smell, in truth, is sufficiently proved by their admirable skill in tracking out, over hill and dale, the most fragrant flower-parterres and beds of mountain-heath. The sense of *hearing* has been denied to bees by many observers, while others describe the antennæ as their organs of hearing. The probabilities are in favour of the latter supposition. Noise, produced by the wings, and varied to suit particular purposes, is well known to be used as a mean of intercommunication; and Huber, though doubtful about the faculty, avers that by a particular sound, emitted from the mouth apparently, the queen will render the whole hive silent and motionless in one instant. A certain sound, too, heard in the hive before swarming, is always followed by definite consequences. Such facts as these go far to establish the possession of hearing by bees; as signals by sound, made when the eyes could not detect the movement attending their production, would otherwise be valueless. The antennæ certainly possess a delicate sense of *touch*. Huber points out a moonlight night as the best time for observing the uses of the antennæ in this respect. The bees, guarding against the intrusion of moths, have not light enough to see fully, and they circumambulate their door with the antennæ stretched right before them. The instant a moth is felt, it is destroyed. When the queen of a hive is lost, the antennæ form a curious means of spreading intelligence. Bee after bee protrudes its antennæ, and crossing them with those of its next neighbour, disseminates in this way the sad news over the hive. Besides the antennæ, the feelers have been shewn by experiment to possess a considerable degree of sensibility, and to serve in part as organs of touch.

Drone. Queen. Worker.

Such are the anatomical and physiological characteristics of the common or working bee. The duties of this order include almost the whole business of the bee community. Hives differ greatly, of course, in the number of their inmates, taking them even at the same season. Some contain but a few thousands; others from twenty to thirty, forty, and even fifty thousand. Of these the drones compose but a thirtieth part, or little more; all the rest, with the exception of the queen, are workers.

Drones or Males.

The drones or males differ considerably in outward appearance from the workers: they are bulkier and flatter in body, with a round head, a shorter proboscis, and antennæ with an additional articulation; they have no basket-cavity on their hind-legs, and their abdomen contains the means of secreting neither honey, wax, nor poison, while the reproductive organs are there found instead. They are called drones from the peculiarly loud noise which they make with their wings. They live but for the reproduction of the race, and when the object of their existence is accomplished, they are doomed to die. The workers, who have their own winter-food and that of the coming young to provide, instinctively pass sentence of death at the fitting time; despatch the defenceless males with their stings, and cast them forth from the hives, in which, from their size and voracity, their presence has now become a positive evil. A merciless massacre of the drones regularly takes place at the end of summer.

Queen-bees.

The queen-bee is of larger size than either the drone or the worker; she has an elongated body,

blackish above, and tinted with yellow inferiorly, while the presence of two ovaries or egg-receptacles in the abdomen demonstrates her sex. She has also a sting, considerably bent. The Germans call the queen the *mother-bee;* and this is the most appropriate name, since her functions are those of a parent rather than a potentate. Her sole province is to lay the eggs, from which issue those annual multitudes that perpetuate the race in new communities. The queen usually commences laying eggs on the fifth day after she has assumed the perfect state, and often continues without intermission from early spring to the end of September, laying in the warmest season about two hundred eggs a day.

NATURAL ECONOMY OF THE HIVE.

The breeding of young bees commences in February, and a hive, however thinned by the previous winter, becomes, under ordinarily favourable circumstances, crowded to excess in midsummer. Besides the developed bees, it abounds in eggs and young ones not matured. That fine instinct which, in the case of bees, occasionally prompts to acts almost above the power of reason, relieves this crowded state of things. The queen-bee, the proper mother of at least the great body of the hive, resolves upon departure with a swarm. The phenomena attending that departure will be noticed under a separate section; in the meantime, let it be supposed that the queen has led off a colony, and that, by the care of the owner of the bees, the swarm is lodged in a new and empty hive.

The first object of the community is to clean out their new lodging thoroughly, if they find this not done beforehand. The next great object is to block up all the chinks of the hive, smooth its projecting parts, and lay a stable foundation for the future works of the interior. Besides the wax which they use so extensively in their architecture, bees also employ, particularly at first, a remarkable substance called *propolis*, from the Greek words *pro* and *polis* (before the city), as indicating its use on the superficial parts of the hive. Propolis is a grayish-brown resin, of an aromatic odour, and better fitted by its tenacity for cementing than wax. Bees gather this from the poplar, alder, birch, and willow trees. In the heat of the day, when the viscous matter is ductile, it is thus carried off by the insect. A small thready portion is detached, kneaded with the mandibles, and then, by means of the fore-feet, placed in the basket of the hind-legs, a smart pat or two being given to secure it there. Another portion, similarly kneaded to make it portable, and a little drier, is basketed in the same way, till as much is procured as the insect can carry. Sometimes the patient creature will spend half an hour in the mere kneading of a portion of propolis; and occasionally other bees will come behind and rob the little labourer of its whole load, for a succession of times, without eliciting the slightest symptom of impatience. When a bee reaches the hive with its load, the propolis adheres so firmly, that the insect has to present its limbs to the workers in the hive, who detach it, and immediately use it, while yet ductile, to fill all the crevices of the hive, and smooth the projecting parts. Another remarkable use is made of the propolis. From the hour of their entrance into the hive, bees are liable to the intrusion of other creatures. A fly they can soon remove, but what are they to do with a snail? They can sting it to death, to be sure, in an instant, but their puny strength is totally insufficient to remove the carcase. In this dilemma they completely obviate the disagreeable effects of the presence of a large putrefying body by covering it with propolis, which hardens over the mass, and gives a pleasant aroma in place of a fetid odour. With the propolis, moreover, they often narrow the entrance to the hive, forming a secure barrier, when they have reason to dread the intrusion of the death's-head moth, their great enemy in some countries.

In the meantime, while some workers are using the propolis for the purposes first stated, others are commencing the preparation of the cells or combs. The propolis is employed to attach these to the edges of the hive, but wax is the component material of the cells themselves. We shall find, in noticing the after-arrangements of the completed hive, that the working-bees are naturally divided into two great classes; but at the outset of their labours, when the cells are being constructed, they form *three* sections, each of which pursues its allotted toil with admirable order and regularity. One section produces the material for the combs, and forms it roughly into cells; the second division follows the first, examines and adjusts the angles, removes all the superfluous wax, and perfects the work; while the third band passes continually out and in, seeking and bringing provisions, chiefly pollen, for the second section, which never quits the hive. The first class fly abroad at intervals, it being necessary that they should have rich saccharine food for the secretion of the wax. As the secretion goes on best in a state of repose, bands of the wax-producers, after feeding fully, suspend themselves in clusters from the roof, each hanging from the hind-legs of the one above, till the wax-scales are formed, and they are prepared to take up the work. This clustering occurs on the very entrance of a swarm into a hive, when a seeming inactivity of several hours takes place, till the production of wax is set agoing. It will be seen that the second section, the architects proper, have the most unremitting toil to perform. They never quit it when once begun, excepting to turn to the little waiters of the third section, and indicate their hunger by holding out their trunk; when the caterer either spirts out a drop or two of honey, or furnishes pollen from the stores brought in.

Cells.

But if the labour of the architect class be severe, their work, when complete, is a marvel of instinctive ingenuity. Bees always begin their work, in ordinary circumstances, at the ceiling, suspending their structures from it. Their combs are arranged in vertical and parallel plates, with a space of about half an inch betwixt contiguous pairs; and each comb is nearly an inch in thickness. At the outset, when one wax-making bee leaves the suspended cluster alluded to, and lays the foundation of a cell, others follow in rapid succession, not only adding their wax to that of the first, but soon commencing new combs, one on each side; and so the work goes on, in most cases, until the whole roof is covered with foundations. The architects proper, also, are meanwhile at their finishing-work. They

have, says Reaumur, to solve this difficult geometrical problem: 'A quantity of wax being given, to form of it similar and equal cells of a determinate capacity, but of the largest size in proportion to the matter employed, and disposed in such a manner as to occupy the least possible space in the hive.' Wonderful to reflect upon, this problem is solved by bees in all its conditions, in their construction of hexagonal or *six-sided* cells. The square and the equilateral triangle are the only other two figures which could make the cells all equal and similar without interstices. But cells of these figures would either consume more material or be weaker; and they would also occupy more space, besides being less adapted to the form of the bee. In short, the hexagonal form combines all the requisites of economy and capacity. Another wonderful arrangement is seen in the construction of the bottoms of the cells. Each of these is composed of three rhombs or plates of wax in the shape of card diamonds, disposed in such a manner as to form a hollow pyramid, the apex of which forms the angles of the bases of three cells on the opposite side, giving to each of them one of the three diamond-shaped plates which is required to form their bases. Now, the three rhombs, composing each cell-bottom, have the two obtuse angles each of 110 degrees, and, consequently, each of the two acute angles of 70 degrees. Koenig, on being desired by Reaumur to calculate the exact angle which would give the greatest economy of wax in a cell of such figure, found that the angle should be 109 degrees 26 minutes, or 110 degrees nearly. Other geometricians have arrived at similar conclusions. The problem is one of great difficulty, yet the bee practically solves it at once, under the guidance of the Great Geometrician who made both the bee and the law on which it proceeds. Attempts have been made to ascribe the form of the cells to the peculiar shape of the head of the bee, and the instruments which it employs; but all such explanations have been found liable to insuperable objections.

The cells of the bee are extremely delicate, two or three plates or sides being of the consistence only of a common leaf of paper. They are made strong, however, by mutual support and other means. Besides a sort of froth which the insect mixes with the wax, the cells, at first of a dull white, soon appear yellow on the interior, the change arising from the plastering over them of a compound varnish of wax and propolis. Each cell is soldered, too, at its mouth by a similar compound of a reddish colour, having in it more propolis; and threads of the same substance are laid around the walls, to bind and strengthen them. It is now to be observed that all cells are not alike. They have four different uses in the economy of the hive, and are constructed variously to suit these. One set of cells is for holding the eggs or embryos of worker-bees; a second for those of males or drones; a third for those of young queens, hence called royal cells; and a fourth set is for the reception of honey and pollen. The first are generally about five lines in depth (or less than half an inch), and two lines and two-fifths in diameter. The cells of the young males are much less numerous, and measure from six to seven lines in depth, by three and a half in diameter. It is worthy of note, that in passing from the construction of worker-cells to those of drones, in the same comb, the architects do not alter the size at once, but gradually, thus disordering in the slightest possible degree the delicate arrangement of the bases of the cells. In shifting from larger to smaller, the same rule is observed. A small number only of royal cells, about ten or twelve, are constructed on ordinary occasions. They are about an inch in depth, and nearly one-third of an inch in width, with walls about an eighth of an inch in thickness. After the breeding season is over, the cells both of worker and male bees are used for holding honey. Those made purposely for that end are chiefly marked by a greater divergence from the horizontal plane, that the honey may be better secured; and it is curious to observe that, in a very warm season, these wise insects give the floor a still greater dip from the mouth inwards. As the store enlarges, they seal up the mouth with a ring of wax, to which they gradually add concentric layers till the cell is filled, when they close it altogether—reserving its treasure for use during winter and spring. Pollen, as brood-food, is kept in cells of considerable size.

Laying of Eggs.

A very short time elapses ere a great number of cells are constructed; for, in the height of the honey season, a good swarm has been known to build *four thousand* in a day. The queen-mother very soon begins the task of laying eggs. A thousand conjectures have been hazarded as to the mode in which the fecundation of the female bee takes place. No observer has yet been able to discover any contact with the drones in the hive. It was supposed by Swammerdam that a certain *aura* or odour from the males was all that was necessary to render the eggs of the queen productive; while M. Debrau imagined that the eggs, as in the case of frogs and fishes, were fecundated by a fluid from the drone after being laid. M. Hattorf thought, again, that the queen was fecundated by herself alone. All these opinions Huber refuted in a satisfactory manner, by separations and confinements of the insects in various ways. He at length came to the belief, founded on experiments which appear almost decisive of the question, that the female bee never becomes fruitful in the hive, but requires to go abroad for that purpose; and it has been also thought probable that the fecundation takes place by contact in the air, as is known to occur in the case of winged ants. The number of drones in a hive has been thought a most unintelligible circumstance. Huber's views explain the matter fully. It is essential that they should be numerous, that the female may have a chance of meeting them abroad; and it is to be observed that she always quits the hive at the hour when the drones leave it, or immediately afterwards. One intercourse is sufficient, according to Huber's experiments, to render the female bee productive for at least two seasons; and if the intercourse takes place at the end of the year, the consequent laying of eggs may be deferred till the ensuing spring. The cold weather has a powerful influence in this respect

M. Huber discovered that the queen begins to lay eggs forty-six hours after returning from the flight during which fecundation takes place. For the space of eleven months, under ordinary circumstances, a queen, at her first laying, produces

the eggs of worker-bees alone. At the end of the time mentioned, a considerable laying of the eggs of drones commences; and soon after the appearance of these, the workers of the hive, with a strange instinct, begin to prepare royal cells for the queen-eggs that are certain to follow. Altogether, the fruitfulness of the female bee is amazing, from 100 to 200 eggs a day being the usual amount of her produce: 100,000 is said to be no very uncommon number of young for her to give origin to in a single season. A swarm consisting of 2000 or 3000 in the beginning of the year will throw off in June swarms amounting to 40,000 or 50,000; in many cases the first swarm, and in some the cast or second swarm, throw off colonies of 10,000 or 12,000; and yet the original stock is left augmented to the number of 18,000 or 20,000. Occasionally, an early and numerous first swarm casts even twice.

Transformation of Worker-bees.

A fertilised queen is so impatient to begin her laying of worker-eggs, that in a new hive, she only waits till a few inches of comb are erected. Before depositing the egg, she carefully examines the cell, and if satisfied, turns and drops into it from the oviduct an egg of an oval shape and bluish-white tint. Here the egg remains for three days, attached by a viscous fluid to the corner of the cell; and, on the fourth, the thin outer shell of the egg bursts, exposing a small lively worm. Now come into play the *nurses*, or nursing-bees, one of the two great sections into which Huber and others consider the labourers of the hive to be divided. The other class are the *wax-workers*. Both elaborate honey, but the latter class alone make wax and form combs. Again, the nurses, whose figure may be distinguished from its being more ovoidal than the others, are those who alone take care of the young. As soon as the egg is hatched, they watch over the larva or worm with the tenderest and most incessant care, administering copious supplies of mixed pollen, honey, and water, which the nursling devours with avidity. Like other larvæ, it soon grows so as to cast its cuticle; and, five days after chipping the shell, it has become large enough to fill the cell, lying coiled up like a ring. It now ceases to eat, and the bees seal up the cell with wax. Left to itself, the larva begins the process of spinning a cocoon round its body, which it does in thirty-six hours, the material being a fine silken thread from the mouth of the spinner. In three days more, it is converted into the state of *pupa*, or chrysalis, when all the parts of the future bee become gradually visible through the transparent covering, assuming a darker hue day by day, and progressing to the state of the complete *imago*, or insect. On the twentieth day from the deposition of the egg, the young bee begins to cut through its prison-door with its mandibles, and in half an hour makes its escape. The bees immediately clean out the vacated cell, and prepare it again for eggs or honey, leaving the silk cocoon adhering to the walls. Old writers say that the elder bees fondly caress and feed the new-comer; but later observers, of no mean authority, declare that, on the contrary, they seem to think their duty ended with the closing up of the cell, and leave the young stranger to shift for itself in the busy world upon which it has entered.

Male Eggs—Royal Eggs.

The passage of male eggs through the larva and pupa state is attended with the very same phenomena as in the case of the eggs of workers, with the exception that the process occupies a little more time, twenty-four days in all being spent in the change. The cause of male eggs being laid, in ordinary circumstances, only after eleven months have been passed in the laying of worker-eggs, was explained by Huber. He conceived eleven months to be necessary to perfect the male eggs, and was of opinion that the arrangement of the eggs in the ovaries was such as to permit, and even compel, the retention of both male and royal eggs until they were fully matured. This idea seems to be confirmed by the ordinary course of things in the hive, but certain anomalous facts startlingly contravene it. Huber himself found that if a young queen had not the opportunity of proving fertile within twenty days of her birth, all her after product consisted of drones, and drones alone; and what is still more curious, he discovered that she began to produce these drones at the time when she should have laid worker-eggs—namely, within forty-six hours after fecundation. The gestation of eleven months seemed totally unnecessary in such cases of retarded fecundation. Huber confessed himself incapable of explaining this remarkable circumstance Though we do not understand it, however, it only tends to make us marvel more and more at the perfection of order in the bee economy. The queen bee is never voluntarily guilty of that breach of the laws of her being, which produces such remarkable effects; and, if artificially confined till she is twenty days old, her violent agitation shews her instinctive sense of the departure from the order of nature.

The raising of workers and drones from the egg to the insect state is a simple matter, in comparison with the same transition in the case of queen-bees. The royal eggs, which the queen begins to lay twenty days after she has commenced the deposition of male ones, differ in no respect from common eggs. But on the royal larva, when it breaks from its three days' confinement in the shell, the nurses bestow peculiar attentions. They watch it incessantly, and feed it with a rich *jelly*, slightly acidulous, and given in such quantities that the royal cell is usually wet with it. In five days, the young majesty of the hive has grown so as to be able to spin her web, and the bees wax up the cell. The cocoon is spun in twenty-four hours; two days and a half of inactivity follow; the larva is then transformed into a pupa or *nymph;* and after other four or five days have passed, the royal insect is complete—the whole time occupied in the metamorphosis being about sixteen days.

Young Queens.

Young queens do not issue from their cells when perfect, like workers and drones. They are not permitted, unless the old queen has quitted the hive with a swarm, or the seat of royalty is in any other way vacated. The bees therefore close the royal cells more firmly, leaving only a small aperture to introduce food; and, acting as if aware that they may need a queen in case of swarming, they at such times will not permit the old queen to approach the cells. Her

struggles to do so are often violent, and her dire hostility to her own sex leads her, if she gets near the cells, to destroy them instantly, whether in the state of full insect or nymph. The strength of this instinctive hate is even such that a young queen no sooner leaves her own cell than she feels its stirrings. According to Huber, there can only be a single queen in a hive. The first thought of a young queen is to kill her yet undeveloped rivals. If two quit the cell at the same instant, they rush into combat with the most headlong fury. In all ordinary circumstances, two queens, brought into contact, fight. But they might *both* die in the contest, and the community be left without a queen. Nature demands but one victim, and she has arranged that but one victim shall fall. Bees are only vulnerable in the belly; and Huber observed that, whenever two royal combatants were so locked together that they could mutually plant their stings in the fatal part, their instinct caused them to separate precipitately, without harm on either side. The combat only closes when one can get an advantage of position, and kill its rival with safety. Again, the worker-bees might interpose to prevent these mortal combats. On the contrary, their instinct is to prevent the queens from parting, and force on a fatal issue. Alluding to one battle, Huber says that it seemed as if 'the bees anticipated the combat in which these queens were about to engage, and were impatient to behold the issue of it, for they retained their prisoners only when they appeared to withdraw from each other; and if one less restrained seemed desirous of approaching her rival, all the bees forming the clusters gave way, to allow her full liberty for the attack; then, if the queens testified a disposition to flee, they returned to inclose them.'

Another remarkable provision for insuring the existence of but one queen in a hive is beheld in the peculiar mode in which the royal larvæ spin their cocoons. Other bees spin perfectly close cases; the queen-larvæ spin cocoons which envelop only the head, thorax, and first ring of the abdomen, leaving a part open behind. Huber thus explains this minute but important peculiarity: 'Of several royal nymphs in a hive, the first transformed attacks the rest, and stings them to death. But were these nymphs enveloped in a complete cocoon, she could not accomplish it. Why? Because the silk is of so close a texture that the sting could not penetrate, or if it did, the barbs would be retained by the meshes of the cocoon, and the queen, unable to retract it, would become the victim of her own fury. Thus, that the queen might destroy her rivals, it was necessary the last rings of the body should remain uncovered; therefore, the royal nymphs must only form imperfect cocoons. Hitherto philosophers have claimed our admiration of nature in her care of preserving and multiplying the species. But from the facts I relate, we must now admire her precautions in exposing certain individuals to a mortal hazard.'

Loss and Making of a Queen.

If bees, by death or artificial means, are deprived of their queen, the event has a marked influence in the hive. In such a case, the following results ensue, according to Huber: Bees do not immediately observe the removal of their queen; their labours are uninterrupted; they watch over the young, and perform all their ordinary occupations. But in a few hours, agitation ensues; all appears a scene of tumult in the hive. A singular humming is heard; the bees desert their young, and rush over the surface of the combs with a delirious impetuosity. Then they discover their queen is no longer among them. But how do they become sensible of it? How do the bees on the surface of the comb discover that the queen is not on the next comb? It is supposed that the alarming intelligence of the loss is communicated by the strokes on the antennæ, which bees are uniformly observed to give to each other at these times. The insects then appear to seek for their lost queen, some rushing hurriedly out to make the search abroad. At the end of five hours, the commotion greatly ceases, and an instinctive recourse to the means of supplying the vacancy takes place. If they have royal larvæ, they turn their whole attention to them. If they have only the larvæ of working-bees, they immediately select two or three of them, pull down the neighbouring cells, at the cost of the lives of the young within them, and construct a royal cell around each of the selected larvæ. If they have no larvæ at all on the loss of their queen, still they build several royal cells. If a stranger queen be introduced in such a state of things, within twelve hours after the loss of their own sovereign, the new-comer is treated as an intruder, and the bees surround her so closely that she commonly dies from privation of air. If the stranger be introduced within eighteen hours, they also surround her, but leave her sooner. To shew that they possess memory, it is only necessary now to re-introduce their own queen, when they will shew every symptom of recognition and joy. But their memory is short-lived; for, if the stranger be not introduced till twenty-four hours elapse, she receives a treatment very different from that experienced at an earlier period. 'I introduced,' says Huber, 'a fertile queen, eleven months old, into a glass hive. The bees were twenty-four hours deprived of their queen, and had already begun the construction of twelve royal cells. Immediately on placing this female stranger on the comb, the workers near her touched her with their antennæ, and passing their trunks over every part of her body, they gave her honey. Then these gave place to others that treated her exactly in the same manner. All vibrated their wings at once, and ranged themselves in a circle around their sovereign. Hence resulted a kind of agitation, which gradually communicated to the workers situated on the same surface of the comb, and induced them to come and reconnoitre, in their turn, what was going on. They soon arrived; and having broken through the circle formed by the first, approached the queen, touched her with the antennæ, and gave her honey. After this little ceremony they retired, and, placing themselves behind the others, enlarged the circle. There they vibrated their wings, and buzzed without tumult or disorder, and as if experiencing some very agreeable sensation. The queen had not yet left the place where I had put her, but in a quarter of an hour she began to move. The bees, far from opposing her, opened the circle at that part to which she turned, followed her, and formed a guard around. She was oppressed with the necessity of laying, and dropped her eggs. Finally,

after an abode of four hours, she began to deposit male eggs in the cells she met with.

'While these events passed on the surface of the comb where the queen stood, all was quiet on the other side. There the workers were apparently ignorant of a queen's arrival in the hive. They laboured with great activity at the royal cells, as if ignorant that they no longer stood in need of them: they watched over the royal worms, supplied them with jelly, and the like. But the queen having at length come to this side, she was received with the same respect that she had experienced from their companions on the other side of the comb. They encompassed her, gave her honey, and touched her with their antennæ; and, what proved more satisfactorily that they treated her as a mother, was their immediately desisting from work at the royal cells: they removed the worms, and devoured the food collected around them. From this moment the queen was recognised by all her people, and conducted herself in this new habitation as if it had been her native hive.'

If one queen is not so introduced to supply the loss of another, and no royal larvæ exist, one of the most wonderful phenomena of the hive takes place. It has been stated that bees, on losing their queen, build a royal cell around an ordinary worker-bee larva, or several of them, if the larvæ are abundant. These, by peculiar feeding, are formed and developed into *queens;* proving that the worker bees, commonly viewed at one time as neuters, are in reality undeveloped females. This remarkable discovery was made by Schirach. Huber proved the same thing by experiment. 'I put some pieces of comb, containing workers' eggs in the cells, of the same kind as those already hatched, into a hive deprived of the queen. The same day several cells were enlarged by the bees, and converted into royal cells, and the worms supplied with a thick bed of jelly. Five were then removed from these cells, and five common worms, which, forty-eight hours before, we had seen come from the egg, substituted for them. When they had hatched on them seven days, we removed the cells, to see the queens that were to be produced. Two were excluded almost at the same moment, of the largest size, and well formed in every respect. The term of the other cells having elapsed, and no queen appearing, we opened them. In one was a dead queen, but still a nymph; the other two were empty. The worms had spun their silk cocoons, but died before passing into their nymphine state, and presented only a dry skin.'

Swarming.

Swarming usually takes place, in temperate climes, in May and June, though additional swarms, and swarms from swarms, are commonly later. In noticing the proceedings of a community from its first settlement, it was mentioned that the old queen led off the first swarm, which she does as if under alarm at the number of royal embryos, usually from twelve to twenty, which were in progress to maturity, and which the worker-bees would not allow her to approach. Other causes also operate, beyond doubt, in a certain degree. The increased heat of the hive from crowding, for example, in all likelihood influences the movement. Bees cannot do without freedom of respiration and fresh air, and it has surprised many observers to find the air usually pure, and below 80 degrees, in a hive ordinarily filled. The insects, however, have been discovered to manage this by active ventilation in their own way. A number of them are always to be seen near the inner, and sometimes the outer side of the opening of the hive, vibrating their wings with great rapidity, and sending the entering air backwards in a smart current. One band relieves another at this task. But when the hive gets overcrowded, the heat often rises to about 100 degrees; the bees are driven to the door, where they hang in clusters, while the warmth makes the hive visibly moist. At the same time, the old queen's alarm at the growth of the royal young seems to have its influence. She would fain kill them, but the worker-bees lose all respect for her, biting and beating her off with violence. The way in which they defend the royal young at swarming-time is indeed most remarkable. If, at any other season, they bring up queens from worker-larvæ, the first queen that leaves the cell is allowed to kill the rest at pleasure. But when casting colonies, the workers, as if from the sense that various swarms may be cast off, and various queens required, will not permit the old queen to touch the young, whom nature has given them the strange power of keeping alive, for better security, in their cells.

Huber says: 'The longest intervals we have observed between the departure of each natural swarm have been from seven to nine days. This is the time that usually elapses from the period of the first colony being led out by the old queen until the next swarm is conducted by the first young queen set at liberty. The interval between the second and third is still shorter; and the fourth sometimes departs on the day after the third. In hives left to themselves, fifteen or eighteen days are usually sufficient for the throwing of the four swarms, if the weather continues favourable, as I shall explain.

'A swarm is never seen except in a fine day, or, to speak more correctly, at a time of the day when the sun shines and the air is calm. Sometimes we have observed all the precursors of swarming—disorder and agitation—but a cloud passed before the sun, and tranquillity was restored; the bees thought no more of swarming. An hour afterwards, the sun having again appeared, the tumult was renewed; it rapidly augmented, and the swarm departed.

'Bees generally seem much alarmed at the prospect of bad weather. While ranging in the fields, the passing of a cloud before the sun induces them precipitately to return. I am led to think that they are disquieted by the sudden diminution of light. For if the sky is uniformly obscured, and there is no sudden alteration in clearness, or in the clouds dispelling, they proceed to the fields for their ordinary collections, and the first drops of a gentle shower do not make them return with much precipitation.'

The capture of the queen, when a swarm has settled on some bush or tree, is the first step towards lodging a swarm in a new hive. If she be placed in it, with two or three bees, the rest will soon follow. A strong glove will enable any one to handle the bees without risk, as they are less

disposed to sting when they are swarming than at other times. It sometimes happens, however, that a swarm may settle on the person of any individual who may be near, in which case presence of mind is absolutely necessary for the preservation of life, perfect stillness being indispensable until the queen is removed, when all the bees will follow.

Massacre of the Drones.

Another of the great natural phenomena of the hive is the massacring of the drones. It was at one time asserted that the worker-bees did not use their stings against the stingless males, but merely pushed them out to die. This idea, however, resulted from the massacre being always committed at the bottom of the hive, whither the poor drones retire in clusters in July and August, as if aware of the doom impending over them. As usual, by one of his ingenious expedients, Huber discovered the truth. Six swarms were put on glass tables, beneath which the watchers placed themselves. 'This contrivance succeeded to admiration. On the 4th of July, we saw the workers actually massacre the males, in the whole six swarms, at the same hour, and with the same peculiarities. The glass table was covered with bees full of animation, which flew upon the drones as they came from the bottom of the hive; seized them by the antennæ, the limbs, and the wings, and after having dragged them about, or, so to speak, after quartering them, they killed them by repeated stings directed between the rings of the belly. The moment that this formidable weapon reached them, was the last of their existence; they stretched their wings and expired. At the same time, as if the workers did not consider them as dead as they appeared to us, they still struck the sting so deep, that it could hardly be withdrawn; and these bees were obliged to turn round upon themselves, with a screw-like motion, before the stings could be disengaged.

'Next day, having resumed our former position, we witnessed new scenes of carnage. During three hours, the bees furiously destroyed the males. They had massacred all their own on the preceding evening, but now attacked those which, driven from the neighbouring hives, had taken refuge amongst them. We saw them also tear some remaining nymphs from the combs; they greedily sucked all the fluid from the abdomen, and then carried them away. The following days no drones remained in the hives.

'The males are never destroyed in hives deprived of queens; on the contrary, while a savage massacre prevails in other places, they there find an asylum. They are tolerated and fed, and many are seen even in the middle of January. They are also preserved in hives which, without a queen, properly so called, have some individuals of that species that lay the eggs of males, and in those whose half-fecundated queens, if I may use the expression, propagate only drones. Therefore the massacre takes place in none but hives where the queens are completely fertile, and it never begins until the season of swarming is past.'

ARTIFICIAL MANAGEMENT—THE APIARY.

The artificial management of the hive forms, in some measure, a distinct branch of the present subject. In the first place, the local situation of an apiary, or accumulation of bee-hives, has been held of especial consequence.

Site of Apiaries.

The hives must be sheltered in a particular manner from the action of high winds. A wall or hedge is not sufficient to yield the requisite protection; houses or lofty trees are necessary to

insure it. The reason of this is, that the bees, returning homewards, require a calm air at a considerable height above their dwellings, otherwise, when they attempt to alight, they are dashed to the ground, and killed, their exhausted strength disabling them from coping with a wind of any force. A low position, inclosed with woods, suits them best. Bees drink much, and a fountain or brook is essential to them; deep pools or cisterns very often cause their death by drowning. Shallow troughs, filled with moss or floating wood, are recommended as a substitute for shallow rills. It is an error, according to the experienced bee-keeper, De Gelieu, to suppose that hives should be placed full in the sun. Bees, he says, live and thrive in shady places of moderate and uniform temperature; hence their partiality for forests. Besides, exposure to all the extremes of the solar heat melts and spoils the honey. In fine, if exposure to the sun be beneficial at all, that exposure should last only for a comparatively short time, or from about ten o'clock till noon. Hives should not be placed on upper floors, on account of the increased danger from wind. At the same time, a bee-house ought to be so made as to cause a free passage of air, though not of strong currents, at all periods, with openings both anteriorly and posteriorly. A covered shed or veranda is perhaps the best form of a bee-house, yielding both a shade from the heat and shelter from the wet. Where hives are simply placed on open stands, these should be about sixteen inches from the ground, and three or four feet apart. Quiet is necessary to their successful operations; and it has been found that they do not thrive well in the neighbourhood of smithies, mills, steam-engines, and the like, partly, we believe, on account of the noise, and partly owing to the smells emitted from such works.

As to the district of country, that of course will always be preferable which yields such vegetable productions as the insect can turn to account. 'Large heaths, sheltered with woods,' says the *Naturalist's Library*, 'are extremely productive of honey, as the wild thyme and other flowering plants with which they abound are not cut down

by the scythe; and the heath itself remains in bloom till late in the season. The plane-tree, the whole willow tribe, the furze or whin, the broom, especially the Spanish kind, furnish a rich store both of honey and farina. Bees do not feed indiscriminately on every species of flowers; several of the most splendid and odoriferous are wholly neglected by them, while they select others, the flowers of which are extremely small, and not apparently possessed of any valuable qualities. Moreover, they give a decided preference to those spots where a *great quantity* of their favourite flowers grow together. On the continent, fields of buckwheat afford a copious supply, though the honey extracted from it is of a coarser kind; and in our own country, the white clover will, in fine weather, be found thronged with them, while scattered plants that afford more honey are neglected. When a variety of bee-flowers flourish in the same field, it is said they will first collect from those which furnish the best honey; if, for example, several kinds of thyme grow together, they prefer the lemon variety, which is of a sweeter and richer fragrance.

'But while mainly depending, as they must always do, on the natural products of the country, the bee-master will do well to supply his favourites with such flowers, &c. as are not found growing spontaneously in his neighbourhood. In addition to the gooseberry, currant, and raspberry bushes, and the several orchard trees, the flower-borders in his garden should be well stocked with snowdrops, crocuses, wall-flower, and, above all, the mignonette, which affords honey of the richest flavour, and which continues flowering till the near approach of winter. The rich melliferous blossoms of the *Buddlea globosa*, too, the bees are very fond of; and some of the *Cacalia* tribe afford an ample store. "The *Cacalea suaveolens*," says Darwin, "produces so much honey, that on some days it may be smelt at a great distance from the plant. I remember once counting on one of these plants above two hundred painted butterflies, which gave it the appearance of being covered with additional flowers." Besides these, the plants of borage and viper's bugloss yield a very considerable quantity of the rich liquid. The former is eagerly resorted to by the bees; it is an annual, and blossoms during the whole season, till destroyed by the frost. In cold and showery weather, the bees feed on it in preference to every other plant, owing to its flowers being pendulous. The bugloss appears as a troublesome weed among corn, and grows on dry soils in great profusion; it is a biennial plant. Turnips, particularly the early garden kind, should be sown, and allowed to remain in their beds during the winter; and they will in consequence, by their early flowering, afford a seasonable supply of farina, and also a small portion of honey early in spring. The whole cabbage tribe also may be made to contribute their share; and mustard, when sown in successive crops, will continue to blossom for many weeks together.'

Hives.

The important question of the size, form, and materials of the hive, or artificial habitation, has of course received much attention. Whatever be the form adopted, it is found that bees accommodate their labours to it, and fashion their combs of honey accordingly.

Straw hives, of which a sketch is given in the preceding page, are those most commonly used in cottage-gardens; and being easily and cheaply constructed, they still maintain their place, though much better kinds of hive have been suggested. They are of a dome shape, ordinarily measuring about twelve inches deep and nine inches wide in the lower part. Made of unbroken straw, and well bound, they will, if tolerably well sheltered, last many years. It is customary to place sticks across the interior, from an idea that they are necessary for supporting the combs; but Mr Taylor, in his *Beekeeper's Manual*, combats this opinion. 'The sticks,' he says, 'are only an annoyance to the bees; and there is little fear of the combs falling, except in very deep hives; at anyrate, it may be prevented by contracting the lower part a little. The best way of doing this is by working a wooden hoop inside the bottom band of the hive. The hoop gives greater stability to the hive, preserves the lower edge from decay, and affords facility in moving it. Of whatever material the outer covering consists, it must protect the hive from moisture. This cannot be too much guarded against; hives ought to be well painted at the beginning, and periodically afterwards.'

Wooden hives are superior to those made of straw, the square shape being better adapted for the deposit of combs than the round form. Mr Taylor's observations may be quoted on this important point. 'It matters not much of what wood the boxes are made, provided it is sound, thoroughly seasoned, and well put together. Different opinions are entertained as to the best size of bee-boxes, but I think that much must depend on the number of bees they are to contain, and on the honey locality; there must also be a reference to the proposed mode of working them; for where no swarming is permitted, a larger hive may be advantageously used. A good size is twelve inches square and nine inches deep within; the thickness throughout being not less than an inch. The top of the box ought to project on all sides nearly three-quarters of an inch, for better protection and appearance, and as affording convenience for lifting. On the top, a two-inch hole should be cut in the centre, for placing a bell-glass, and for the purpose of feeding; and another hole, to receive a ventilator, may be made near the back window, that position being better for inspection, and less in the way of the bees, than the centre of the hive, which is, or ought to be, the seat of breeding, and should not be disturbed. A window may be placed at the back and front, five inches high, and six or seven inches wide. The best and neatest way of securing the windows that I have seen, is by a sliding shutter of zinc.'

To these explanations it should be added, that the hive of either form must be placed on a clean wooden floor or board, raised a foot and a half from the ground; and if there be several hives together, each should have its own separate floor. Do not cement the hives to the board, that being a duty which the bees will themselves perform. The entrance to the hive requires to be small, a little larger than a shilling, but rather wider than deep, and ought to be at the lower edge of the hive, on the side which is exposed. Numberless

have been the plans invented to enlarge hives as may be required, both to permit of the greater accumulation of honey, and to render swarming unnecessary. Caps are the simplest of these inventions. In order to use caps, hives must have a stoppered hole at the top. A small additional hive, of light structure, is placed over this at the proper time, the stopper being removed. This serves as a second magazine for honey. Storied hives are merely hives made originally with one or two stories, for the same end. Wildman's hive, the Grecian hive, and Lombard's hive are specimens of hives made on this principle. Collateral hives, again, such as Nutt's, effect the same ends by being placed side by side, and giving increased accommodation, when necessary, either for swarms or stores.

Use of Caps.—Experienced apiarians, who work on a large scale, now employ for the most part hives so contrived as to remedy all the inconveniences resulting from the straggling of swarms and the old custom of killing by brimstone. As the use of single straw hives, however, formed upon the simplest plan, still prevails among those who have but one or two hives in all, the cap may be regarded as the easiest means of affording enlarged accommodation in such cases, and the mode of taking away the honey from it is very plain and easy. It is only necessary to remove the cap, invert it, and cover it with a handkerchief, leaving a little opening on one side. A few taps will cause the bees to quit the cap and return to the hive, after which the honey can of course be readily removed. This may be done frequently in the same season. De Gelieu mentions, that in one season he drew from one of his straw hives that did not swarm seventy-two pounds of fine honey-comb, by merely emptying the caps as they were filled.

One of the cheapest and simplest forms of the capped straw hive is the Improved Cottage-hive, exhibited in the Crystal Palace, in 1851, by Mr

Milton's Improved Cottage-hive.

Milton, and which received a prize medal. It is simply a straw hive of the usual dome-shape, with a wooden hoop round the bottom. The projecting landing-place is sloping and sunk, so as to form an entrance without cutting the edge of the hive. An opening of two inches diameter is left in the top of the hive, and over this is fastened a flat board, not so large as the bottom diameter of the hive, with a similar aperture. The empty space between the top of the hive and the board is filled up with cement or putty. The cap is a smaller hive, adapted to stand on this board, and may be used alone, or to cover a bell-glass. The hole in the board is kept closed by a bung until the bees give indications of swarming, or of having filled the hive; the bung is then withdrawn, and the bees ascend, and fill the glass or the small hive with pure honey. When it is filled, a knife is passed below, to detach any combs that may be adhering to the board, and it is then removed, and another cap put in its place. The bell-glass is represented in the figure with an aperture at top, through which a perforated zinc tube descends, for the purpose of ventilation.

Union of Swarms.

It is strongly recommended by experienced men that swarms should be more often united than they are. Five thousand bees are estimated to weigh a pound; and, according to most bee-keepers, a swarm ought to weigh nearly four pounds. As a hive often casts off successive colonies, each far below this weight, it then becomes proper to unite two or more of them; seeing that one strong population supports itself better, and is incomparably more profitable, than several feeble colonies, which must be frequently in want of assistance. To those who keep bees on a small and cheap scale, convenience also dictates the junction of swarms in such cases. De Gelieu thus describes his mode of practice: 'When two small swarms come off the same day, I gather them separately, and leave them at the foot of the tree or bush on which they have alighted. Towards evening, I spread a table-cloth on the ground, on which, by a smart and sudden movement, I shake all the bees out of one of the hives, and immediately take the other and place it gently over the bees that are heaped together on the cloth, and they instantly ascend into it, flapping their wings, and join those which, not having been disturbed, are quiet in their new abode. Early next morning, I remove this newly united hive to the place it is destined to occupy. This doubled population works with double success, and in the most perfect harmony; and generally becomes a powerful colony, from which a great profit is derived. Two feeble swarms may be united after the same manner, although one of them may have come off some days later than the other, and the first may have constructed combs; taking care, however, not to make the first one enter the second, but the second the first, as the bees will ascend more readily to join those that have already begun to make honey and to hatch brood; and next day they will proceed together with increased ardour with the work which the first had already begun, and which will now advance more rapidly from the increase of the labourers. It is to be understood that, after this union, the hive should be placed early next morning in the same place where the oldest of the swarms has already passed some days.' On many occasions, the circumstance of two queens passing out at once is the cause of a colony going off in two halves, and the removal of

one of the queens is necessary, to facilitate their cordial junction into one community.

Besides the union of young swarms, it is often advisable to reunite weak swarms with their parent stocks, to unite weak stocks with each other, or even to add to some weak community a portion of one more numerous and healthy. In either case the object is the same—namely, to obtain well-filled, strong, and consequently more active hives. The three usual modes by which union has been attempted, and, indeed, their advocates say accomplished, are—fuming them, immersing them in water, and aspersing them with sugared or honeyed ale. To these we may add a fourth—namely, operating upon their fears, by confining them for a time, and then alarming them by drumming smartly upon the outside of their domicile. By operating on their fears, Wildman was enabled to perform extraordinary feats with bees. 'When under a strong impression of fear,' he says, 'they are rendered subservient to our wills to such a degree as to remain long attached to any place they afterwards settle upon, and will become so mild and tractable, as to bear any handling which does not hurt them, without the least show of resentment.'

The neatest and most scientific mode with which we are acquainted of uniting weak families together in harmony, was invented by the Rev. Richard Walond, whose experience in the management of bees, for nearly half a century, entitles his opinions concerning them to great respect. His theory and practice upon this subject are as follows: 'Bees,' says he, 'emit a peculiar odour, and it is by no means improbable that every family of bees emits an odour peculiar to itself; if so, as their vision seems to be imperfect, and their smell acute, it may be by this distinctive and peculiar odour that they are enabled to discriminate betwixt the individuals of their own family and those of a stranger hive. Upon this supposition, if the odours of two separate stocks or swarms can be so blended as to make them completely merge into each other, there will then probably be no difficulty in effecting the union of any two families that it may be desirable to unite.' To accomplish this end, therefore, Mr Walond had recourse to a very ingenious contrivance. He confined, in their respective hives or boxes, the two families to be united, and placed them over each other, with only a perforated tin plate between them. Immediately the bees began to cluster with hostile intentions, one family clinging to the upper, the other to the under side of the perforated plate; when, after remaining in this state for about twenty-four hours, they had so far communicated to each other their respective effluvia, and so completely commixed were the odours in both hives, that on withdrawing the perforated plate, the bees mingled together as one family: no disturbance was excited, but such as arose from the presence of two queens, one of which soon killed the other. Keys has observed that these incorporations seldom turn to account unless they are effected in summer. Fumigation, however, is the easiest and surest operation. The plan is as follows: In autumn, three or four puff-balls—a kind of fungus growing in meadows, and commonly called the 'Devil's Snuff-box'—must be pulled before they are fully ripe. These are thoroughly dried in an oven, and kept dry till wanted. A round box, made of thick tin, without any solder, is to be provided, about two inches in diameter, and an inch and a half deep; with a conical movable top, about an inch and a half high, perforated with holes. The bottom must also have three holes in it. With this box, and a piece of a puff-ball about the size of a hen's egg, in readiness, the operator commences by fixing an empty hive, of the same size as that from which he intends to take the bees, securely, in an inverted position. A sharp-pointed stick having been stuck into the empty hive, so as to stand upright within it, the box is fixed thereupon by inserting the stick into one of the holes in its bottom. The piece of puff-ball is then lighted and put in the box, over which the conical lid is placed. The hive from which the bees are to be taken is then placed over the empty hive and the burning fungus. To keep all close, a wet cloth is put round the place where the two hives join. In a minute or two, the bees may be heard dropping heavily into the empty hive, where they lie stupefied. After a short lapse of time, the full hive may be tapped, to cause the bees to fall faster. On removing the upper hive, the bees from it will all be found lying quiet at the bottom of the lower one. The queen may be taken from them and placed under a glass with a little honey on a small piece of comb. The stupefied bees must then be sprinkled freely with a thick sirup made of sugar and ale boiled together. The hive containing the bees with which it is intended to unite the stupefied bees, must now be placed on the top of that containing the latter, just as the hive was from which they have dropped. A cloth must be closely fastened round the two hives, so as to prevent any of the bees from escaping. The hives in this position must be put aside, where they will not be likely to be thrown down or disturbed. The bees in the upper hive, attracted by the scent of the sirup, go down, and begin to lick the sprinkled bees clean. The latter gradually revive, and all get mingled together, and ascend quietly in company to the upper hive, where they dwell as if they had always been one family. The two hives should be left undisturbed for twenty-four or thirty hours, at the end of which time the upper hive is to be removed and placed immediately on the spot from whence it was taken. The object of taking the queen away is to avoid all risk of disagreement. It is, however, recommended to preserve her as long as she will live, lest any accident should happen to the sovereign of the other community.

Summer Management of Bees.

The feeding of bees at different seasons is an important point to the bee-keeper. In summer they feed themselves, and of course a good supply of the requisite material is then essential to their well-doing. The most highly cultivated districts are not so favourable to bees as those in which wild heaths, commons, and woods prevail; or where white clover, saintfoin, buckwheat, mustard, and cole-seed, are produced in abundance. Bee-keepers, however, may do something to further the supply of summer food by growing near their apiaries a selection of such plants as we have recommended under a previous section. But on the natural products of the country, generally speaking, bees must rely for summer food, if the

weather be such as to permit of their gathering it. Should a succession of coarse bad weather occur, however, at the beginning of summer, and particularly after a swarm has entered a new hive, most apiarians think it essentially necessary to give honey, or a sirup of sugar and water, to the newly hived stock. If no proper brook or fount be at hand, water should always form a part of the summer provision. The bees being at full work in this season, the door of the hive should be opened to its whole extent. In hives formed upon improved plans, ventilators are used, but they are not essential. Where artificial ventilation can be effected, it is recommended that the temperature should be maintained at from 65 to 80 degrees Fahrenheit.

Autumnal Management.

The autumnal period has long been the most calamitous for bees, not through the injuries of enemies or weather, but from the improper management of bee-keepers. After the carcases of the drones, strewn in multitudes before the hive, have indicated that, with the beginning of August, has come the close of the rich honey season, the bee-keeper deems it time to take from the hive the reward of his care and attention. The use of storied hives or extra boxes renders it easy to take away a portion of honey early in the season, and this is called *virgin honey*. Even with a common straw hive, it has been found possible to take away the honey, and retain the bees in the hive. Wildman, the famous experimenter on bees, recommended that the hive should be taken into a dark room, and there struck repeatedly till the bees are forced to ascend into an empty hive. The combs are then cut out with a thin knife, and the bees finally returned to the old hive. But this plan is seldom pursued, being at once dangerous and destructive to the brood combs.

It is generally reckoned advantageous to change the pasturage for a week or two before taking the honey-harvest. About mid-autumn, the ordinary food of bees begins to fail, and their stock of honey to decrease daily. By a removal of three weeks to a heathy district, a hive not only loses nothing, but frequently gains as much as ten or twelve pounds of honey in ordinarily favourable circumstances. So well is this known by bee-keepers near Edinburgh, that one shepherd on the heathy Pentland Hills receives in charge several scores of hives annually, for the heath-feeding.

Bees are transported from place to place in vessels on the Rhine, the Nile, and some other rivers, in order that advantage may be taken of the succession of flowers in different districts. The transporting of bees from one pasture to another was also anciently practised in Greece.

Honey-harvest.

After the autumnal accession of honey has been obtained, and the bees have been brought home again, the question comes to be, in what manner the harvest should be reaped. By partially depriving each of a portion of comb, and leaving some for food? By suffocating one half the communities, taking their entire honey, and leaving the other hives with their honey untouched, to serve as stock? Or finally, by removing the bees from one half the hives to the other half, forming united stocks, and acquiring all the honey of the evacuated ones? The cultivator who uses box hives, may easily, immediately after the swarming season is over, add another story or box to his hive, placing it undermost. The brood combs contained in the uppermost story will, as the young bees are hatched, be quickly filled with honey, and may be removed about the beginning of August. The top cover is then replaced on the next story in position, which was originally the lower, and is now the upper. In ordinary seasons, the bees will have ample time to lay in sufficient food for winter and spring use, after the abstraction of this portion of their stores. As the combs of the upper box are frequently found adhering by their lower extremities to the bars of the next, it will be necessary before removal to separate them by means of a very thin long-bladed knife, or a fine wire drawn through the hive at the point of junction. The operator will next expel the bees from this box or story, by lifting the top cover, and blowing in a little smoke, which will cause the inhabitants to retreat quickly to the lower regions. The box may be then taken away, without the operator running the risk of the slightest annoyance. The honey found in this removed box will not be all honey of the current season, and consequently is not so delicately fine. It is also sometimes found mixed with, or rather deposited above a layer of farina. Should it be wished, therefore, to obtain a supply free from these impurities, the empty story which is added may be placed *above*, instead of *below* the original stock, and the honey will thus be of a superior kind. Large quantities of the purest honey may be obtained from common straw hives, by placing on the top of the hive, when the swarming season is over, a small hive of the same form and material—called in Scotland an *eke* or *top-eke*—and opening a way of access to it by a hole in the top of the hive. If the season is favourable, it is soon filled. This practice is now very general in Scotland.

One argument employed by advocates of the plan of suffocation by introducing the fumes of brimstone or other noxious effluvia is, that by the union of stocks you have an immense number of mouths to feed, of which the killing plan relieves you. Only inexperienced bee-keepers, however, could use this reasoning, De Gelieu having discovered the remarkable fact, that the increase of numbers in the winter hives is far from producing a proportionate increase of consumption. From fifteen to twenty pounds of honey, or from three to four pots, are requisite for the winter maintenance of a single hive of ordinary strength, with which the plan of union has not been practised. De Gelieu placed such a hive, with such a store, beside one into which three full communities had been introduced; and he found, on weighing the latter in the spring, that its inhabitants had scarcely used one pound of honey more than those of the single-stocked hive. The experimenter even went further. To a hive already amply stocked, he added the swarms of *four* other hives, and found, on weighing it in the spring, that 'the total diminution of honey did not exceed three pounds more than took place in ordinary single hives.' Had they not been thus united, he says, each of these stocks would have cost him much more honey than they were worth, and indeed the most of them 'would to a certainty have perished.' The cause

of this strange fact, by which nature seems to point to the plan of autumnal unions as the best possible for both bees and bee-keepers, is yet unknown.

The combs, by whatever process procured, should be deprived of the honey at once, while a natural warmth remains in them. The honey which runs off naturally without breaking down the combs, and passes through muslin, is the finest. A second kind is procured by cutting the combs in pieces, and letting the honey pass through a drainer, under exposure to a gentle heat. A third quality is procured by subsequently putting the combs in a vessel placed on a fire; the product strained through canvas, is used in feeding bees. The separated wax of the combs is introduced into a woollen bag, firmly tied at the mouth, and put into boiling water. The pure wax oozes through, and is skimmed off the surface, where it floats. It is then to be allowed to cool slowly. The best honey is supposed to be that formed from heath. The famous bees of Hymettus were nourished by that plant.

Honey is used as a condiment at the table, and is also employed in medicine. Its value is rarely under 2s. a pound. In Britain alone, about £120,000 is annually spent for foreign supply; and if we add to this a large home production, and consider that in other countries the article is even more liberally made use of, we shall arrive at some conception of the economical value of the bee. But it is not the honey alone; we import 10,000 hundredweight of wax each year; and when we state that the price varies from £5 to £10, 10s. a hundredweight, it will be seen that its value is all but equivalent to that of honey.

Winter and Spring Management.

In winter and early spring, bees require to be tended with great care. In the case of those hives which have been entirely deprived of their honey, systematic feeding is of course indispensable in winter; but few bee-keepers of any experience ever willingly follow any other plan than that of leaving to bees a winter supply of their own produce. Some bee-keepers remove their hives into the house in winter; but this seems an unwise practice, as the bees must then be kept continually in confinement. Though the door of the hive should be carefully narrowed or shut up in very cold weather, at which time every bee that issues perishes, yet advantage should be taken of every fine day to let them abroad. On this point, however, great difference of opinion exists—many contending that the bee naturally becomes torpid in winter, object to their exposure to sunshine altogether, and for that purpose recommend screens and coverings. One thing is certain, that a moderate degree of warmth is necessary, and that this warmth should be as equable as possible; while at the same time there should be the most thorough precautions against damp. It is damp more than cold which kills our hives in winter; and he who protects them from cold and wet by a thorough covering of straw, fern, flax refuse, or the like, plastered over with Roman cement, is sure to have the healthiest apiary.

Proceeding on the 'dormancy' theory, a singular device for winter preservation has been resorted to by some bee-masters—namely, *burying the hives.* When this is to be attempted, the hive should be buried in a cool, dry, shady place, among leaves about a foot deep, and the interment should be performed during the first or second week of November. Mr Briggs, who first made public this device, records the following experiments: 'A friend in the vicinity of Hitchin buried a hive of bees in the first week of November, about a foot deep among dry leaves, &c. and disinterred it in the last week of February, when it was just *two pounds lighter than it was in November, and the bees in a lively and healthy state.* Another person, residing in Leicester, immured a hive of bees in the earth, four feet deep, in the second week in November, and at the end of January it was removed, and weighed *only three ounces less than it did before it was buried.*'

Where feeding is necessary, the following rules have been laid down for the management of hives in winter and early spring: Bees must be fed only when the weather is fine and warm, to prevent the temperature of the hive from being injured; and a large quantity should never be given at once. The quantity of food which ought to be given to a hive may be calculated in the proportion of two pounds a month; but if the weather be very cold, a less quantity will suffice. When a hive is fed in the spring, it should always be after sunset, when the bees have returned from the fields; otherwise, the most disastrous consequences may ensue, from the robberies committed by the bees of other hives. If fed in the morning, it must be before sunrise, and the entrance instantly stopped, to keep out depredators; for as bees leave the hive on the very first appearance of daylight, a later period would prevent the return of those which had left the hive previous to the entrance being secured.

Relative to the substances which are proper for the feeding of bees, many different opinions exist; but the following may be considered among the most beneficial as well as economical articles of diet: To two quarts of good ale put one pound of moist sugar; boil them until the sugar is wholly dissolved, carefully skimming it; when it is cold, it will be found of the consistency of honey, and it may be given to the bees in the following manner: If the bees are in the plain cottage-hive, an eke of the same diameter as the hive must be provided, and from three to four hands in height. When the sun is set, and the bees have retired, let the hive be gently raised, and the eke placed on the stool; then, having filled a soup-plate with the food, place it in the eke, and put down the hive. To prevent the bees being drowned in the liquid, it is necessary to place some straws over the plate, and over the straws a piece of paper, either thickly perforated or cut into nicks; these nicks, however, must not run parallel with the straws, but either across or diagonally; the entrance must then be closed, and the plate removed on the following morning, when the whole of the liquid will have been transferred to the combs. In order to avoid lifting up the hive for the purpose of feeding, some recently invented hives have a drawer under the bottom board, into which a shallow vessel containing the food is put, access to it being opened for the bees by drawing out a tin slide in the bottom board. The food is covered with a float of thin cork or wood, pierced with holes. In others, the feeding-saucer is placed on the top of the hive, under a

bell-glass, and the bees allowed to ascend through an aperture.

Diseases and Enemies of Bees.

Bees, according to the conclusions of De Gelieu, after sixty-four years' experience, 'are always in good health as long as they are at liberty, and when they are warm enough, and have plenty of food.' In early spring, however, they are found liable to an affection called dysentery, which is known by the marks on the board of dark-coloured evacuations, by the offensive smell, and by the frequent deaths. This disease certainly results, in most cases, from long confinement in a damp and impure air. By lifting the hive to expel the vitiated air, scraping, washing, and drying the board, and removing the dead bodies, the complaint, says Mr Taylor, may soon be remedied, even in the most extreme cases. A little chloride of lime, he suggests, may be used beneficially in washing the board. One point should be noticed here, that exposure to the sun, in winter, is held decidedly injurious to the hives. This caution is necessary, as bee-keepers, when they suspect dampness, might fall into an error on this score. While on this subject, we may also mention a new remedy, which is said to have been adopted on the continent with success. When dysentery begins to shew itself in the apiary, the bee-keeper prepares a sirup composed of an equal quantity of good wine and sugar, which is administered to the bees by placing it within the hive in a saucer, or any other shallow vessel.

About the end of spring, another disorder sometimes makes its appearance, which Du Carne de Blangy calls vertigo. This is supposed to be occasioned by the poisonous properties of certain plants on which they feed. The symptoms are manifested by a dizzy manner of flight, by their involuntary startings, falls, and other gestures in attempting to perform their usual operations, or in approaching the hive, and by the lassitude that succeeds these symptoms. This distemper has been hitherto found incurable. Bees, according to the same authority, are liable to a third distemper, the symptoms of which are swelling at the extremities of the antennæ, which become also much inflamed, and of a yellow colour; the head assuming shortly after the same tint, the bees lose their vivacity, and languish till they die, unless a proper remedy be applied. In France, they give them Spanish wine for this disorder. There is still another distemper which sometimes makes its appearance among bees, for which the continental agriculturists administer Spanish wine, as in the former case. This is a kind of pestilence, by which many of the insects are cut off. It happens when the larvæ are killed by the cold or otherwise, the numbers that die infecting the rest. The only attention requisite in this case is to remove the infected combs, perfume the hive with aromatic plants, and give the bees wine to sip.

A few hints from Gelieu and others, respecting the chief foes of the bee tribe, may be useful to bee-keepers. Gelieu, after observing that the possessors of bees, often from an ignorant excess of care, are among their greatest enemies, says: 'Ants are their least dangerous enemies: true, the bees cannot sting them to death, because they are small and well defended with armour, but they seize hold of them with their teeth, and carry them to a distance. Had they not this means of getting rid of them, their colonies could not exist in the vast forests full of ants' nests, and where they thrive so well, in spite of the horrible massacres that annually take place.

'Moths are little known, and never injurious, in the high valleys or on the mountains; but they attack and destroy a vast number of hives in the plains or in the vineyards, where they are a great scourge. Huber discovered that the *Sphinx atropos*, or death's-head moth, was one of the most destructive of this tribe. As soon as a moth has penetrated a weak hive, it establishes itself in a comb, envelops itself in a silken web, multiplies rapidly, consuming the wax, and spreading its destructive galleries from side to side, until, arriving at a certain point, the evil has scarcely a remedy. The only means of saving the colony is to imitate the surgeon, who cuts off a diseased limb to save the other—every bit of infected comb must be cut out, leaving only those occupied by the bees. The bees must then be liberally fed, by giving them every evening as much honey as will maintain them, until such time as the field-flowers shall again yield a sufficient quantity. Thus,' concludes Gelieu, 'I have preserved hives whose circumstances seemed to be desperate.

'Spiders annoy the hive much. The bees get entangled in their webs, and are not able to extricate themselves. Here cleanliness is the best protection; therefore, care should be taken to sweep the webs away from the hive and its avenues as fast as they appear.

'Birds, such as the sparrow, house-lark, and swallow, eat a prodigious quantity of bees, especially in spring, when the trees are in blossom. Poultry, also, that roam about or near the water where the bees go to quench their thirst, gobble up a great many. Fowls should never be permitted in any apiary.

'Mice, especially the red mouse, or *Sorex araneus*, sometimes penetrate a hive in the winter-time, either from the entrance being left too wide, or by gnawing a hole for themselves in the straw. They eat the honey, and even the bees, when clustered together on the side of the hive, in which position they are unable to defend themselves, and scarcely even see the enemy. The most effectual preventive against rats and mice is to place the hive on stands with projecting ledges, and in such a position that they cannot reach it.

'Wasps are also reckoned among the numerous enemies of bees. I have, however, seldom seen a hive destroyed by wasps; although they are larger, stronger, and armed with a formidable sting, and an impenetrable cuirass, they seldom dare enter a well-stocked hive. Once attacked, they soon fall beneath the united efforts of these brave citizens, who sacrifice themselves to defend the place of their nativity. Wasps only appear in great numbers when the fruit is ripening, and then they range unceasingly round the hives, and enter the weak ones, or those of which the too spacious lodging bears no proportion to the number of its inhabitants. There are three ways of providing against the attacks of wasps: the first is, to unite weak hives by doubling or tripling the population, thereby enabling them to defend themselves; the second is, to contract the entrances, as soon as swarming-time is over, after the massacre of the drones; and the third is, to destroy with assiduity all the nests

of wasps that can be discovered in the neighbourhood.

'Bees are subject also to a peculiar species of *pediculus*, called the bee-louse. Hives that have swarmed more than once, and such as contain but little honey, are most exposed to those troublesome vermin. The hives in this case should be cleared at the furthest once every week, and the stools on which they stand every morning; for the latter are likely to harbour the larvæ and moths, or other insects, as well as the hive. But these obnoxious creatures cannot be entirely extirpated without taking away the infected hive, removing the bees, and cleaning it, before it is restored to the former station. The lice are of a slender shape, or filiform, and of a ferruginous colour, and may be destroyed by strewing tobacco over the bees.

'The bees are continually fighting among themselves, and robbing each other: avarice, not necessity, leads them to do so, it being almost always the strongest and best provisioned hives that pillage the weak ones. When once a bee has been able to introduce itself into a hive, and carry away a load of honey without being arrested, it will return a hundred times the same day; and, making it known to its companions, they will then come in hordes, nor cease their pillage until there is nothing left to take. In one day, the whole of the honey will be carried off, and with a determination which one can scarcely have an idea of without seeing it. This kind of pillage is most frequent in the spring and autumn, and it is easier to prevent than to stop it; and, for this purpose, the entrance of the hives ought to be straitened in proportion to the population.'

Ligurian Bee.—Hives of the Ligurian bee (*Apis Ligustica*), already mentioned, may now be purchased in London, but at a cost which places them beyond the reach of many bee-cultivators. Ligurian bee-queens may, however, be obtained at a more moderate price; and by introducing one of these into a hive of common bees, it may gradually be converted into a hive of Ligurian bees. The bees readily receive the stranger, if their own queen is removed. But it does not yet appear that there is any economical advantage. The Banded Bee of Egypt (*Apis fasciata*) has not yet been introduced into this country.

BRITISH WILD BEES.

Besides the hive-bee, already mentioned, there are various species of bees, natives of Britain, which have never been domesticated by man, though some of them construct hives and produce honey. Of these wanderers of the wilds, the most common is the *humble*-bee (*Bombus*), of which there are several species, the smallest of them at least double the size of the hive-bee.

On account of their peculiar habits, these wild species are unfitted for domestication. Few of them survive the rigours of winter; but one, a female, that does escape, manages for a season the resuscitation of the breed. Abroad it flies in early summer, and, alone and unaided, sets laboriously to work in constructing its nest, piercing the earth or moss, as its instinct may be, and excavating a small chamber wherein to lay its eggs. It does not make wax and cells for the young. These come to maturity in the cocoons which they spin for themselves in the larva state; and when they emerge, these cocoons form stores for food. The solitary bee feeds alone its earliest progeny, but these soon multiply around it, make more cells, gather honey, and feed the increasing young. Towards the middle or latter part of September, however, the energies of the bees begin to wax fainter, and little further progress is made in adding to the colony, or in collecting honey. Cold and showery days begin, even by this time, to thin the number of the insect population, which are now seen creeping slowly, with damp and heavy wings, upon the stalks and petals of flowers, where they were formerly seen actively buzzing about in search of honey. The stores of the honey-cups have not outlasted the wants of the young unfledged bees, of which they were the proper food; and if the nests be examined now, these cups are found quite empty. The surviving bees by degrees forsake the nest and its furniture, leaving the latter as a prey to mice, beetles, or other animals. To shelter themselves for the winter, they seek out some dry bank, where they penetrate to the depth of eighteen inches or two feet, pushing up the soil behind them, and leaving no visible track by which they have descended. In these situations they are often found by labourers and others while digging; and such people are often greatly puzzled to imagine how the insect can have reached such a depth. Those who have attended to the habits of wild bees can readily fix on the spots where they take refuge.

The experiment of domesticating wild bees has been tried; and it was found that, by removing their nest cautiously in an evening, and placing it in a quiet situation, in a garden or other place where they could be observed, they went on with their works without apparent alarm or interruption. During the whole summer, they continued to prosecute their occupations with the same industry as other bees; but about September, as we have mentioned, the hive began to turn languid, and the numbers which appeared going and coming about the entrance became daily smaller. It was imagined they had taken refuge within the hive; but when this was opened, after all seemed to have ceased their labours, everything was found empty and deserted; there were neither bees nor honey; the stronger and younger insects, no doubt, having gone to make burrows for themselves in the earth, and the older ones having gradually fallen victims to the accidents of approaching winter. Our wild bees, therefore, appear to possess their brief lives but for self-enjoyment, or rather to form one of that order of beings created by the great Author of all, as if for the purpose of leaving no corner of the universe without its utmost allotment of sentient and enjoying existence.

THE DOG—FIELD-SPORTS—ANGLING.

THE DOG.

According to naturalists, the dog belongs to the family *Canidæ*, which includes the wolf, fox, and jackal. It is generally agreed that the different breeds of the domestic dog are merely *varieties*, and not distinct *species*. But the question as to what was the parent stock is still undecided; some zoologists hold that the breed is derived from the wolf, others that it is a tamed jackal. Into this and other difficult questions of the natural history of the dog, we refrain from entering, and proceed to make some remarks on

EFFECTS OF TRAINING.

In no case is the fact of animal educability more strikingly demonstrated than in that of the dog. The original animal is only supposed to have been gifted by nature with a fine scent for game, and a disposition to make a momentary pause on seeing it, for the purpose of springing upon it. Man has converted this inclination to a temporary pause into a habit of making a full stop, or point, as it is termed; and the animal, instead of gratifying his destructive tendency by springing upon the game, has been trained to be contented with witnessing a vicarious execution by the gun of his master.

It is a mistake to suppose that only the spaniel tribe is capable of serving sportsmen in the capacity of pointers and setters. Mr Blaine (*Encyclopædia of Rural Sports*) is of opinion that this power can be cultivated in most dogs. It has even been elicited in another and very different class of animals—the hog. Some years ago, Mr Toomer, gamekeeper to Sir Henry Mildmay, bethought him of teaching a pig to act as a pointer, having been struck by the scenting powers of the animal in its search for palatable roots under ground. He began by allowing a young female pig to accompany his pointers, in their breaking-lessons, to the field. Within a fortnight, to his own surprise, she was able to hunt and point partridges and rabbits. There being an abundance of these creatures near the keeper's lodge, her education advanced rapidly by frequent exercise, and in a few weeks she was able to retrieve game as well as the best pointer. *Slut*, as this extraordinary animal was called, was considered to have a more acute scent than any pointer in the charge of the keeper; and he kept a kennel of the highest character. They hunted her principally on moors and heaths; and it often happened, that when left behind, she would come of her own accord and join the pointers. In consequence of the dogs being not much inclined to hunt when she was with them—for they dropped their sterns and shewed symptoms of jealousy—she did not very often accompany them, except for the novelty. Her pace was mostly a trot; she was seldom known to gallop, except when called to go out shooting; she would then come home from the forest at full stretch, and be as much elated as a dog on being shewn the gun.

But the most wonderful effect of training is the transmission of *acquired qualities* by animals to progeny. The habit which education has conferred upon the pointer appears in his puppy, which may be seen earnestly standing at chickens and pigeons in a farmyard, before he has ever accompanied his seniors to the field, or received the least instruction. Here only the object is amiss; the act itself is perfect. On the subject of the hereditary transmission of acquired qualities by animals, we have some curious information from the naturalist, Mr T. A. Knight, in a communication to the Royal Society in 1807. 'In all animals,' he says, 'this is observable; but in the dog it exists to a wonderful extent; and the offspring appears to inherit not only the passions and propensities, but even the resentments of the family from which it springs. I ascertained that a terrier, whose parents had been in the habit of fighting with polecats, will instantly shew every mark of anger when he first perceives the scent of that animal, though the animal itself be wholly concealed from his sight. A young spaniel brought up with the terriers shewed no marks of emotion at the scent of the polecat, but it pursued a woodcock, the first time it saw one, with clamour and exultation: and a young pointer, which I am certain had never seen a partridge, stood trembling with anxiety, its eyes fixed and its muscles rigid when conducted into the midst of a covey of those birds. Yet each of those dogs are mere varieties of the same species, and to that species none of these habits are given by nature. The peculiarities of character can therefore be traced to no other source than the acquired habits of the parents, which are inherited by the offspring, and become what I call *instinctive hereditary propensities*.'

GENERAL CHARACTERISTICS OF THE DOG.

The general form and aspect of the dog is too well known to require any description. He has six incisory or cutting teeth in both jaws; beyond which there are, on each side, both above and below, a canine tooth; and still farther into the mouth are six cheek-teeth, or molars, in each side of the upper jaw. The first three are sharp and cutting, which Cuvier calls false molars. The next tooth on each side is a carnivorous tooth, furnished with two cutting lobes, beyond which the other two teeth on each side are flat. There are seven cheek-teeth, on both sides, in the under jaw; four of these are false molars, a carnivorous tooth, with the posterior part flat, and behind it two tuberculous teeth. The muzzle is elongated, subject to great variety of length in different varieties. The tongue is smooth and soft; the ears erect in the wild varieties, and in some of the tame ones, but, in the latter kinds, for the most part pendulous.

The fore-feet are provided with five toes, and the hind-feet with four toes, furnished with rather longish nails, obtuse at their points, and not retractile. Occasionally a fifth toe occurs on the hind-feet, termed the *dew-claw;* this is generally removed by the sportsman when the animal is young, as its presence is calculated to impede the animal's movements. The dew-claw is regarded as a sign of degeneracy. The females are provided with both inguinal and ventral teats. The pupils of the eyes are circular.

The female goes with young sixty-three days, and generally produces from three to five at a birth, and sometimes even twelve, which are at first blind, continuing so for from nine days to a fortnight. About the end of two months, their faculties begin to develop themselves. They shed their first teeth at the end of six months, which are replaced by others that do not exfoliate. At twenty months or two years, dogs arrive at their full vigour. The males continue to propagate for nearly their whole lives, while the female discontinues having young ones at about the age of eight or nine years. The average age to which dogs live is about fourteen years; they frequently, however, live to sixteen, and even have been known to attain the age of twenty years.

The dog is naturally carnivorous; but when domesticated, he does not refuse farinaceous food. He uses grass as a medicine; and drinks by lapping with his long flexible tongue. He does not sensibly perspire by the skin; the superfluous moisture of the body escapes at the mouth by panting, when heated, and by the extraordinary diuretic habits of the animal. The sense of smell is different in different varieties, but in all is sufficiently strong and refined to enable the dog to seek out and follow his master even amidst a crowd. His sense of hearing is also quick.

The most remarkable feature in the character of the dog is his attachment to man. In wild unpeopled countries, dogs are known to live in hordes, and seek their prey like other untamed animals; but brought into connection with human society, the dog leaves his own species without regret, and is only happy when belonging to a master to whom he can be faithful as a friend, servant, or companion. In this condition of domestication his ambition seems to be the desire to please. Much more mindful of benefits received than injuries offered, he is not driven off by unkindness: he still continues humble, submissive, and imploring; his only hope to be serviceable, his only terror to displease: he licks the hand that has just been lifted to strike him, and at last disarms resentment by submissive perseverance.

More docile than man, as Buffon observes, more obedient than any other animal, he is not only instructed in a short time, but he also conforms to the dispositions and manners of those who command him. He takes his tone from the house he inhabits: like the rest of the domestics, he is disdainful among the great, and churlish among clowns. He knows a beggar by his clothes, by his voice, or his gestures, and forbids his approach. When at night the protection of the house is committed to his care, he seems proud of his charge; he continues a watchful sentinel; he goes his rounds, scents strangers at a distance, and gives them a warning of his being upon duty. If they attempt to break in upon his territories, he becomes more fierce, flies at them, threatens, fights, and either conquers alone, or alarms those who have most interest in coming to his assistance.

CLASSIFICATION OF VARIETIES.

No satisfactory classification of dogs has yet been attained. We will follow that made by the French naturalist Cuvier, which is founded on the shape of the head, and length of the jaws and muzzle. He separated dogs into three great groups, as follows:

I. MATINS.—These have a head more or less elongated; the parietal bones insensibly approaching each other, and the condyles of the lower jaw placed in a horizontal line with the upper cheek-teeth.

II. SPANIELS.—The head moderately elongated; the parietal bones do not approach each other above the temples, but diverge and swell out, so as to enlarge the forehead and cavity of the brain. In this group are included all the varieties of dogs which are of the greatest utility to man, and also the most intelligent.

III. DOGUES. — The muzzle more or less shortened; the skull high; the frontal sinuses considerable; the condyle of the lower jaw extending above the line of the upper cheek-teeth. The cranium is smaller in this group than in the two previous, owing to the peculiar formation of the head.

These three groups have, for convenience, been further subdivided into various sections, which we shall now treat *seriatim*—noticing the more important breeds or varieties which have been ranked under each.

I.—DOGS WITH LENGTHENED HEADS.

Section 1.—Half-reclaimed Dogs, which hunt in packs.

The *Dingo, or Australian Dog.*—The head of this dog is not unlike that of a wolf, on which account Bewick calls it the New South Wales wolf. The muzzle is long and pointed, with short erect ears. He is two feet six inches in length, and about two feet in height. His fur is composed of a mixture of silky and woolly hairs, and is of a deep yellowish-brown colour; and his tail is long and bushy, resembling that of a fox, but generally carried curled over his haunch, and not pendent. The dingo, though naturally ferocious, is easily rendered tolerably tame; and in this state many specimens are now brought to this country. They are not to be trusted, however; and the moment they escape from confinement, all their natural blood-thirsty propensities return.

The *Dhole* is the native wild-dog of India, and bears a strong resemblance to the dingo, but without the bushy tail of that species: he is of a uniform bright-red colour. The dhole is exceedingly swift of foot, and soon overtakes most animals which are the objects of his pursuit. It is said they are exceedingly fond of the flesh of the tiger, and that, in consequence, this animal is prevented from multiplying so as to overrun and lay waste the countries which it inhabits.

The *Pariah* is the common village-dog of India. He has a small sharp head, with short pricked ears, and a slender body, and particularly drawn up about the abdominal region; his chest is deep, his limbs light, and his colour is of a reddish-brown. The native Indians use the pariahs in

hunting the tiger and wild-boar. They are very fierce, and follow their game with much avidity and determination.

The *Ekia* is the native dog of Africa, and in all likelihood sprung from the same stock as the dhole.

The *South American Dog* is not unlike the dingo, and is about the size of the springer, with short and pricked ears, like most other wild-dogs. There is another South American dog called the Alco, of which there are two varieties. It is said that the Spaniards found this dog among the natives on the first discovery of America.

Section 2.—Domesticated Dogs, which hunt in packs or singly, principally by the eye, although sometimes by the scent.

The *Irish Greyhound* ranks among the noblest of the canine race. In his general shape he bears a strong resemblance to the common greyhound, but is much taller, and more robust. His use in early times was to free the country of wolves and wild-boars, which abounded in England and Ireland; hence he is sometimes termed the 'Irish wolf-dog.' The ordinary height of the Irish greyhound is about three feet, although it has been known to reach four feet. The *true* Irish wolf-dog is now extremely rare, if not altogether extinct.

The *French Matin* has an elongated head, and flat above; his ears are erect, and slightly pendulous towards the tips; the hair of a yellowish fawn-colour, with darker, oblique, and parallel indistinct rays traversing the whole of his fur. He evinces great eagerness in hunting the wild-boar and wolf, in which sport he is frequently employed. Pennant thinks this variety is a descendant of the Irish greyhound.

The *Scottish Highland Greyhound* will hunt either in packs or singly. He is an animal of great size and strength, and at the same time very swift of foot. In size he equals, if not excels, the Irish greyhound. His head is long, and the nose sharp; his ears short, somewhat pendulous at the tips. He is remarkable for the depth of his chest, and tapers gradually towards the loins, which are of great strength, and very muscular. His usual colour is a reddish sand-colour, mixed with white; his tail is long and shaggy, which he carries high, like the staghound, although not quite so erect. It is this noble dog which was used by the Scottish Highland chieftains in their great hunting-parties, and is supposed to have descended in regular succession from the dogs of Ossian.

Section 3.—Domesticated Dogs, which hunt singly, and always by the eye.

The *Gazehound* is an extinct breed.

The *Greyhound* is the fleetest of all dogs, in consequence of his peculiar conformation. His head is long, tapered, and shaped like that of a snake; his neck long and slender; his ears somewhat erect and pricked, slightly pendulous at their tips: the tail ought to be very fine, curved and pointed, and the hair on it very short; the chest should be wide and deep; the belly drawn up with strong loins, and with large and prominent hip-muscles. This dog is by no means so intelligent as many other varieties, and he is, in consequence, much less susceptible of education. He has, however, very fine feelings, and seems to be much alive to caresses, which excite him to such a degree as to produce a quick pulsation of the heart. This may be felt beating against his side with much vigour. He is one of the most elegantly formed of all the canine species.

The *Scotch Greyhound* is formed exactly like the common greyhound, and differs from it merely by being of a larger size, and in the hair being longer and wiry. The general colour is reddish-brown or sandy.

Fig. 1.—Shepherd's Dog—Scotch and Irish Greyhounds.

The *Italian Greyhound* is merely a miniature of the common greyhound, being only about half the size of that dog. It has a very fine coat of a silky texture, and is so tender as to be easily injured by cold or wet. It is used only as a *pet*, being altogether valueless in other respects.

The *Turkish Greyhound* is still smaller than the Italian greyhound, being little more than half the size. It has no hair except a little on the tail. Its usual colour is a blackish lead-colour. It abounds in Turkish towns, where it is a dreadful nuisance to travellers.

II.—Head less Elongated than Former Division.

Section 4.—Pastoral Dogs, or such as are employed in domestic purposes.

The *Shepherd's Dog* is covered with long, flowing, and somewhat woolly hair; his muzzle is long and pointed, and his ears erect, and slightly bent downwards at the tips; his tail is long and bushy; and the usual colour of his fur black and white, or varied with black and gray; the backs of his fore-legs have also long hairs. The peculiar and highly useful qualities of this dog seem to be rather intuitive than acquired; indeed, scarcely anything can exceed the quickness with which he is taught; and certainly no other dog has the same patient perseverance and courageous fidelity, or greater discrimination. The labour of a shepherd, with the assistance of this faithful and intelligent animal, is comparatively an easy task; and it is hardly possible to fancy a more arduous employment than it would be without it; for without him, how could he collect extensive flocks scattered over high and widely spread mountain-ranges? The shepherd's dog is sagacious, grateful, and self-denying, as is well known from innumerable anecdotes.

The *Cur*, or *Watch-dog*, differs from the shepherd's dog in being nearly smooth; he is stronger

in his make, and has half-pricked ears, and his tail is rather short, and slightly feathered beneath. He is a trusty and useful servant to the farmer and grazier, and is chiefly employed in driving cattle; and being larger and stronger than the shepherd's dog, from which he is sprung, he is better qualified for the grazier and farmer. A cross between this and the true shepherd's dog has been found to be extremely useful on the sheep-runs of Australia.

Section 5.—Water-dogs, which delight in swimming, having their feet in general semi-webbed.

The *Pomeranian*, or *Wolf-dog*, has the hair on the head, feet, and ears short; but it is long and silky on the body and tail, which last is curled up in a spiral form. His intelligence is nearly equal to that of the shepherd's dog, but he is much less to be trusted.

The *Siberian Dog* has much the appearance of the Pomeranian dog, except that he is covered with long hair, even on the head and paws. In their native country, four of these dogs are attached by pairs to a sledge, and in front of them is placed a leader, on the proper training of which much of the useful services of the others depends. These sledges are just large enough to contain one person, who directs the team with his voice, partially assisted by a stick. The reins are fastened to the dogs' necks by a collar. Thus yoked, they have been known to drag a sledge from seventy to eighty miles in a day; and so powerful is their scent, that they contrive to keep on the beaten track by that means alone, even though it be obliterated by fallen snow.

Closely allied to the preceding are the *Iceland*, *Esquimaux*, and *Hare-Indian Dogs*.

The *Newfoundland Dog*.—This beautiful and intelligent dog is remarkable for the symmetry of his form and the acuteness of his understanding. He measures, from the tip of the nose to the point of the tail, six feet and a half, the length of the tail itself being two feet; from the one fore-foot to the other, over the shoulders, five feet eight inches; the girth behind the shoulders, three feet four inches; the length of his head is fourteen inches. He has webbed feet, in consequence of which he is a dexterous swimmer. His hair is long, flowing, and slightly curled. The docility of the Newfoundland dog is very great; there are innumerable most striking anecdotes of his sagacity and benevolence, particularly as shewn in his saving persons from drowning. Intelligent and sagacious as the Newfoundland dog undoubtedly is, there are certain occasions on which he is not to be trusted; and if sharply reproved or punished, he sometimes resists the lash even of his master.

The *Large Water-spaniel* is about the size of the English setter, but of a stronger make. His face is smooth, as also the front of his legs; while the rest of his body is covered with small crisped curls, usually of a dark liver-brown colour. This dog is very valuable in the sport of shooting wild-fowl.

The *Small Water-spaniel*, or *Poodle*, is a breed between the large water-dog and the springer; he is thickly covered with fine hair, all of which is in distinct small curls, more like an effort of art than of nature. It is one of the most active of dogs. Its general colour is white, and sometimes it has various black patches.

Section 6.—Fowlers, or dogs whose inclination is to chase and point birds, and hunt singly by the scent.

The *Springer* is shaped much like the English setter, but shorter in the body and legs in proportion to his size, being about two-fifths less than that dog; the hair is long and shaggy, the ears very long and pendulous, and covered with long waved hairs.

The *Cocker* is about a third less than the springer, and like it in all respects. It is used as well as that variety for raising woodcocks and snipes, in which exercise they are both very expert and hardy.

The *King Charles's Spaniel* is still less than the cocker, and distinguished by the very great length of his ears. Its hair is silky; and this, with its gentleness and small size, has rendered it a favourite pet of ladies. They are sold at a high price.

The *Alpine Spaniel, or Great St Bernard Dog*, exceeds other varieties of the spaniel in size and beauty. Its usual height is two feet at the shoulders; and the length from the nose to the tip of the tail is six feet. Two of these dogs are sent out from the monastery of the Great St Bernard, situated among the Alps of Switzerland, to scour the mountains during snow-storms, in search of lost or wearied travellers—the one with a warm cloak fastened to his back, and the other with a basket tied round his neck, containing a bottle with some cordial, and bread. In this employment they shew great judgment, and seem perfectly to understand their mission.

The *English Setter* is a mixed breed between the water-spaniel, Spanish pointer, and the springer. He ranks highly as a sporting-dog. He is one of the most beautiful, lively, active, and hardy of dogs.

The *Spanish Pointer* is the stock from which the English pointer has sprung. He is one of the most staunch of all dogs used in the sports of the field, although he is considered too heavy for the present improved mode of sporting, and has now nearly become extinct in Great Britain.

The *English Pointer* was obtained by a cross of the Spanish pointer and foxhound, and is unrivalled for the rapidity of his movements in

Fig. 2.—Newfoundland—Scotch Terrier—English Pointer—Cocker.

the field, and the beauty and symmetry of his form. Since his first production, he has been improved by being recrossed with the harrier. He varies a good deal in his size and colour. When well trained, and of a pure breed, he is exceedingly staunch—instances having been known where he has remained above an hour in the act of pointing.

The *Dalmatian* is a handsome animal, beautifully spotted black on a white skin. In his native country he is employed as a pointer; but imported into England, he has there lost all qualities for sporting, and is kept merely as an attendant on carriages—hence the common term 'coach-dog.'

Section 7.—**Hounds which hunt in packs by the scent.**

The *English Terrier* is too well known to require any description. He has great courage, and is famous for killing all kinds of vermin, and at one time formed a useful attendant upon a pack of foxhounds, for getting into the earth when the fox had taken to his hole, and driving him out. His hair is smooth; his general colour is black, with tanned cheeks, and the insides of his legs are of the same colour.

The *Scotch Terrier* has short wiry hair, very rough, and is much shorter in the legs than the English terrier. His usual colour is sandy, but he is to be found black, and also gray. He bites with great keenness, and is a bold and determined dog. He will attack dogs of any size; and when he fixes on an animal, he maintains his hold with great pertinacity. He is an excellent killer of vermin. The *Skye terriers*, or terriers of the Western Isles, are longer in the body, lower in the legs, and decidedly rougher and shaggier than those of the Lowlands; indeed, they form altogether a distinct variety.

The *Bloodhound* is a powerful and sagacious animal, generally of a dark colour, with brown markings, and is endowed with a keen scent. On being led to the footsteps of any animal or man, he will follow them up with unerring precision. This has led to the breed being employed for tracking criminals, or the unhappy victims of oppression. By the Spaniards, a breed was taken to Cuba to track the natives, and this race of animals still exists in that island. A company of them, with their attendants, were imported from Cuba into Jamaica, to assist in putting down the refractory Maroons.

The *Staghound* is the largest of all the British dogs of the chase; he has a noble and dignified aspect, and great sagacity and endurance in the chase: this dog is also supposed to be a direct descendant of one of our original British dogs.

The *Foxhound* has a much larger muzzle than the staghound, and his head is small in proportion to the size of his body; his ears are very long and pendulous, although less so than those of the staghound and bloodhound.

The *Harrier* is used in hare-hunting, and was originally obtained by a double cross between the small beagle and southern hound. He is very eager in the pursuit of the hare. There are few instances of any of the deer tribe being hunted with success by dogs so small as harriers.

The *Beagle* is the smallest of the dogs of the chase. He has a very acute sense of smelling, and pursues the hare with unwearied steadiness; and what he wants in speed and strength, he makes up for by his perseverance.

III.—With Short Heads.

Section 8.—**Watch-dogs, which have no propensity for hunting.**

The *Mastiff* has a large flat head, and a short and blunted muzzle; his lips are full, and hanging considerably over the lower jaw; his ears, although rather small, are pendulous. He has a sullen and grave aspect, and is excellent as a watch-dog; his voice is loud and deep-toned. Like the dog next mentioned, he is ferocious in disposition, and of little use when off the chain.

The *Bull-dog* is remarkable for the depth of his chest and the strength of the whole muscles of his body. His head is large, flattened above, and his muzzle much blunted, with the under jaw projecting considerably beyond the upper. He is the boldest and most obstinate of all dogs, and has been known to hold his adversary so determinedly that his legs have been cut off without making him desist.

Many instances have been recorded of the invincible courage of the English bull-dog, but we scarcely recollect one in which so much unconquerable spirit and tenacity of life have ever been displayed as on the following occasion. Some years ago, a large dog of this species, from some cause that was not observed, suddenly flew at a fine cart-horse that was standing at the end of the Salthouse Dock, Liverpool, and fixing his lacerating teeth in his shoulder, defied every effort to get him off. At first he was beaten with cart-whips and sticks, with much fury; but this being unavailing, a carpenter with an adze in his hand came up and beat him with the blunt iron head of the instrument, but the dog never moved a tooth. A man then took out a large pointed clasp-knife, with which he stabbed him repeatedly in the back, loins, and ribs, but with no better success. At length one of the spectators, who appeared to have more strength of sinew and arm than the rest, squeezed the ferocious beast so tightly about the throat that at length he turned up the white of his eyes and relaxed his jaws. The man threw him off to a distance; but the dog immediately went round the crowd, got behind the horse, and again seized him by the under part of the thigh. As no terms could now be kept with this untamable brute, he was again loosened, and thrown into the dock to drown. He instantly, however, rose to the surface, when a sailor struck him a supposed deadly blow on the head with a handspike, which again sent him to the bottom. He arose once more, and was again sent down in the same manner, and this process was repeated five or six times. At length one of the by-standers, who either possessed or assumed some right of property in the dog, overcome by his amazing tenacity of life, and weary of persecution, got him out, and walked off with this prodigy of English courage, to all appearance very little the worse for the horrible punishment he had undergone. Since the very proper disuse of bull-baiting, this ferocious variety of the dog has fortunately diminished in number.

GENERAL MANAGEMENT.

As formerly mentioned, dogs are very susceptible of education. To make a dog behave properly,

he must be carefully taught when young, and for this purpose his master requires to employ a judicious mixture of severity and gentleness. He must be made fully aware that he must do as he is bid: that if he do not, he will be punished, but that if he obey, he will be rewarded. Thus he will soon learn to comprehend the meaning of a look, a sign, or a word, and will act accordingly. As very few persons take the trouble to teach domestic dogs either one line of conduct or another, we see on all occasions instances of the natural consequences of such neglect.

Breeding.

The best dogs are produced from parents not less than two years old, to which age a valuable bitch should be reserved. All who are interested in preserving the breed of their dogs should on no account suffer a cross. In every instance, let the male and female be of the true breed designed, not mixed or deteriorated. If a slight alteration of character be desirable, a cross of the English bull-dog will be found useful by giving determination. Breed always from the healthiest and best-shaped animals. Mongrel breeds are good for nothing.

Whelps, at a month old, are generally deprived of their dew-claws. With some varieties it is also the custom to shorten the ears and tail, with a view of improving their appearance; but it is questionable if any breed can be improved in aspect by such treatment, and certainly no pure and well-formed variety can benefit by such mutilations.

Feeding.

Some of the most troublesome traits in the dog's behaviour arise from mismanagement in feeding. If a dog be half-hungered, he cannot be blamed for watching the breakfast or dinner table. We advise all who indulge themselves with keeping dogs, not to leave their feeding to the chance scraps of either the kitchen or the parlour. Give the dog his own regular meals, and with food suitable to his wants or the duty he has to perform. The food should be chiefly flesh of some kind, boiled and cold; if given raw, it has a tendency to foster ferocity of disposition, and will cause the animal to be offensive in smell. No pet-dog, especially, should ever be allowed to eat raw meat. Any common pieces of flesh or tripe will answer for dog's meat. Some persons give liver, which is decidedly bad; it relaxes the bowels, and is otherwise objectionable. Besides the piece of boiled meat considered necessary, give dogs a few bones from the dinner-table; they are fond of these, and they are useful in cleaning and preserving their teeth, and keeping their bowels in order. If the dogs will take it, they should also be given a little farinaceous food, as morsels of bread or a little oatmeal porridge with milk.

The nature of the dog leads him to feed well and seldom. One meal a day, therefore, in the morning or forenoon, is enough. He, however, requires to drink frequently; and it is a leading rule, in keeping a dog, to have at all times a pan of clean cold water ready for his use. Change the water daily, or oftener.

For the feeding of hounds, Daniel recommends that flesh should be alternated with a diet of oatmeal porridge made with broth in which meat has been boiled. Greens boiled in their food are also proper.

Lodging—Kennel Treatment.

Dogs require to be lodged in a dry situation, at a moderate temperature. Those kept for watching the outside of premises should be provided with a comfortable house of wood, bedded with clean straw, and sheltered from cutting winds. Damp is seriously injurious to dogs. It produces rheumatisms, which shew themselves by lameness in the shoulders, and other disorders detrimental to their usefulness. The best kennels are paved with tiles or stone, but on the floors there are raised benches, littered with straw in winter, on which the dogs repose. The straw should be daily changed, nothing being of so much consequence as cleanliness, both for the sake of general health, and preserving the powers of scent of the animals. Hounds which are properly disciplined are obedient in a very extraordinary degree to the orders of the huntsman.

Health—Disease.

All dogs whatsoever, but those designed for field-sports in particular, require to be kept in what is called 'condition;' that is, neither too fat nor too lean, but the body in that hardy and active state that will enable the animal to perform its duties.

To keep a dog healthy, he must not only be regularly fed and admitted freely to water, but be allowed plenty of exercise daily in the open air, and kept in a cleanly condition. If his bowels appear relaxed, he is not in sound health; and as a preventive of this, let his food, as already said, be substantial, and consist partly of bones; let him also have access to grass; every proper kennel has a grass-yard to which the dogs can resort. In the pan of water used by house-dogs put a piece of brimstone; it slightly affects the water by lying in it, and helps to keep the animals cool.

All dogs are liable to be troubled with fleas, which they get from the ground; the skin also becomes dirty, and from that or other causes becomes offensive in smell. The remedy is cleanliness. Every lap or house dog should be washed at least once a week with soap and water. Some dogs have a great dislike to washing, but it must nevertheless be performed. After washing thoroughly, rub the animal dry with a hard cloth, and comb and brush it. If there be fleas, a small-toothed comb will remove them, and they should be killed as they appear. Wash and dry delicate dogs before the fire. When there are symptoms of diseased skin, a little sulphur and antimony is recommended, mixed with the food, or done up as a bolus or pill, and pushed over the throat.

Mange is a cutaneous disease in dogs, very closely resembling itch in man, but more inveterate, and is hereditary as well as contagious. Mr Blaine, in his *Encyclopædia of Rural Sports*, thus speaks of this nauseous complaint: 'Of all the causes which beget mange—and they are not few—the acrid effluvium from their own secretions is the most common; when it is generated by numbers, particularly when it is confined within a limited space, it is sure to appear. Close confinement of any dog will commonly produce it, and most certainly so if it be at the same time fed

on salt provisions.' The same authority gives several recipes of medicine to be employed; the leading are—powdered sulphur, four ounces; muriate of ammonia (sal-ammoniac) powdered, half an ounce; aloes powdered, one drachm; Venice turpentine, half an ounce; lard or other fatty matter, six ounces: the whole to be mixed and administered in boluses. In all bad cases, however, we should recommend no one to attempt doctoring his dog, but to apply to a regular practitioner.

Distemper.—This disease is most common among dogs which are much kept in the house and subjected to artificial treatment. The disorder is epidemical, affects the constitution, and is very difficult of removal. It is now considered to be typhus fever, and should be treated on the same principles as that disease in the human subject. The chief symptoms of distemper in a young dog are sudden loss of activity and appetite, emaciation, and excessive weakness. James's powder is recommended as the most likely remedy. A teaspoonful of sulphur given weekly in milk, from the age of three to twelve months, has been found to render the disease very mild. To aid recovery, nourishing diet should be given. In cases of severity, consult the veterinary surgeon.

Rabies, or canine madness, is the most fatal malady to which dogs are subject (for which, in 1884, Pasteur proposed to inoculate with enfeebled germs a milder preventive disease). Rabies is never produced spontaneously in dogs or any other animals, but is invariably the effect of inoculation by a bite from a dog already mad. Rabies is little known in hot or cold countries; it is common chiefly in temperate regions, and—contrary to popular belief—is not more prevalent at one time of the year than another.

The leading symptom of the rabid state is an apparent discomfort and unsettledness of purpose, with a desire to gnaw and eat anything within reach, as straw, wood, coal, or any other rubbish; as the disease advances, the animal snaps and bites at everybody or any animal near it. This is, however, no effect of bad temper; the dog has no wish to go out of his way to bite; he is under the influence of a derangement which makes him catch only at what is near. Like the unnatural appetite he possesses, the snapping propensity may also partly arise from the irritated state of the stomach and intestines, both of which are greatly inflamed. The throat is likewise livid, and by a constriction of parts, soon prevents the animal from swallowing. *Hydrophobia* is the name of a human disease produced by the bite of a dog affected with rabies. In it the dread of water is the most marked symptom, whilst in rabies there is a decided desire for water. In the later stages of rabies, paralysis ensues, and from the fourth to the seventh day the dog expires. It is humanity to shoot the animal before this final catastrophe.

Grave doubts have been raised whether the bite of mad dogs does really affect the human species with hydrophobia. It seems, however, to be established that, although the majority of persons bitten escape the disease without taking any precaution, yet a large proportion become victims. The disease does not manifest itself till after a period of incubation varying from six weeks to eighteen months. Early excision of the bitten part is the only sure preventive. Even when the operation has been omitted at first, it is advisable to have recourse to it later, so long as the poison continues latent. When the peculiar symptoms once begin to manifest themselves, all remedies seem to be unavailing; there is no well authenticated case of recovery on record. The most distressing symptoms, however, may be alleviated by chloroform, opiates, &c.

FIELD-SPORTS.

In such sports, the true English gentleman prides himself on avoiding every proceeding which can give unnecessary pain to the animals, and on discountenancing such odious abuses of sport as baiting, worrying at the stake, and any other method of protracting the death of the objects of the chase. Our limited space will permit us to notice only the leading field-sports of Britain in past and present times.

FALCONRY.

Falconry was the favourite field-sport of the middle ages, as shooting with the gun is of the present day. It appears, in this country, to have declined and gone out of use in the seventeenth century, in consequence of the gun having then become, by the addition of the lock and flint, a much more ready means of bringing down game than hawks had ever been. Falconry was the peculiar sport of kings, and princes, and nobles, many of whom were painted in life with their hawks seated on the wrist, and were sculptured on their tombs after death with the same creature placed at their feet.

DEER-HUNTING.

Deer-hunting was another principal amusement of past times, but has now been abandoned in the form in which it used to be conducted. The species of deer chiefly hunted in England was the fallow-deer, a beautiful creature with stately horns and antlers, and of great speed in running. Fallow-deer are now closed up in parks, at least in Britain. The stag, red-deer, or hart, whose female is called the hind, differs in size and in horns from the fallow-deer. He is much larger, and his horns are round, whereas in the fallow species they are broad and palmated.

Deer-stalking is a sport requiring a vast deal of tact, knowledge of the animal's habits, and patience, as whole days are occasionally taken up in stealthily watching an opportunity for a shot. Such is their power of sight, scent, and hearing, that to approach unperceived on a plain is impossible. They must be approached from down the wind, and from behind thickets or hillocks. A telescope is required in these difficult manœuvres. When it is impracticable to reach them in this artful manner, attendants drive them into gorges among the mountains, and the sportsman singles out an object for his rifle as it passes his concealed station.

FOX-HUNTING.

The variety of fox most common in Britain is called the *cur fox*. It is brown, with generally

some white on the breast and belly, and a light tip to the long bushy tail. Foxes go to *clicket* in winter, and cubs are produced in the latter end of March; they breed but once a year, and have from three to eight young ones at a time.

Fox-hunting on a proper scale requires to be conducted with the class of active horses termed hunters, a pack of foxhounds to scent and run down the prey, and terriers to turn the animal from his hole, should he take to earth. A pack of hounds varies from twenty to thirty couples; but besides these, some hounds are always left undrafted into the field. The cost of a well-bred pack is reckoned at from £1000 to £1200, and the annual expense of its keep and management about as much. The huntsman, as the grand leader of the chase, is a functionary of no small importance; he is assisted by two whippers-in, who bring up and take charge of the hounds.

The fox being an early riser, and his scent lying best on the damp grass, he is hunted in early morning; and the first business on taking the field is to ride to and draw cover—that is, bring out the fox from his retreat. At the first sight, the view halloo is given by the huntsman, and all follow the sweeping track of the hounds. The run is considered the exhilarating part of the sport, and consists of a rapid chase through a broken or rough country, with the hounds in full cry. Then is the ardour of the chase shewn; and it continues till the fox, by some clever manœuvre —such as tracking up a brook—throws the hounds off the scent, and the party is brought to check. The scent and track of the animal being again found, off all go once more in pursuit. When the fox is caught, his *brush* or tail is cut off as a trophy by the huntsman, and his unfortunate carcase is thrown to the hounds.

HARE-HUNTING—COURSING.

Hares are hunted in much the same manner as foxes, the chief difference being, that harriers are employed instead of hounds: both hunt by the scent.

Hares are hunted with packs of generally twenty couples of harriers; but whatever number is employed, it is the established rule not to run in upon the hares as soon as discovered in their forms, but to allow them a little space before the dogs are set on. This space is termed 'law.' The hares also must not be pressed upon in the chase by the company; neither are the dogs, in losing scent, to be called on the right path; for this leads them to depend on the sight of the huntsman instead of their own noses.

Coursing is the chasing and taking of the hare by means of greyhounds, which hunt by the sight only. Among fox-hunters it is considered an inferior kind of sport, but many country gentlemen find in it an exhilarating recreation, and it is patronised by numerous coursing clubs.

The greyhound, whose form so eminently adapts him for competing with the hare in a race, requires to be well trained in the art of turning suddenly, and determinedly pursuing his game on a new line of pursuit. A single pair of dogs is generally sufficient for the sport; and betting often ensues as to the *points* in the course. There are numerous rules of ancient and modern date on the subject of coursing.

SHOOTING—GROUSE—PARTRIDGES, ETC.

The leading sports with dog and gun are the shooting of grouse, partridges, and pheasants. In all kinds of shooting a good gun is the first requisite, and the second is to know how to use and clean it. Next, the sportsman must be provided with dogs trained to point the kind of game for which they are taken to the field: to take a dog accustomed to point partridges on a grouse-shooting excursion would be foolish. The gunpowder should be kept very dry in a metal flask, and be of proper strength and purity. Patent shot is now commonly used; it is of eight sorts, each numbered, and rises from 83 pellets to 620 pellets in the ounce. Much variety of opinion exists as to the proper size of shot; No. 6 is often used on the moors at the commencement of the season, and as the grouse become wilder, No. 4 or 3 is substituted. The more tender the birds, the smaller may be the pellets or drops.

The following hints to a beginner in shooting are worth taking: 'In raising the gun, let him remember that the moment it is brought up to the centre of the object, the trigger should be pulled, as the first sight is always unquestionably the best. Then send him out to practise at a card with powder till he has got steady; and afterwards load his gun occasionally with shot, but never let the time of your making this addition be known to him; and the idea of it being perhaps impossible to strike his object will remove all anxiety, and he will soon become perfectly firm and collected.

'Beware of the muzzle of the gun being kept hanging downwards; when so carried, the shot is apt to force its way from the powder, especially in clean barrels. If it happens that a space of sixteen or eighteen inches is thus obtained, and the gun fired with its point below the horizon, it is ten to one but the barrel bursts.' Again, men, horses, and dogs are in perpetual danger of being shot when a gun is carried in this manner.

Grouse-shooting.—This favourite field-sport, as is well known, commences annually on the 12th of August, when thousands of persons adjourn to remote parts of the country to follow it, with all its toils and privations. Among the varieties of this game are numbered the cock of the wood or capercailzie; the black-cock, heath-cock, black game, or black grouse; the red grouse, moorfowl, or gorcock; and the white grouse or ptarmigan. Moorfowl are the most common, and seem to be peculiar to Britain. They are very plentiful in the Highlands of Scotland, and by no means scarce in any of the wild, heathy, and mountainous tracts in the northern counties of England and Wales. Red grouse pair early in spring, and lay from six to ten eggs; the young brood follow the hen during the whole summer; and in winter they unite in flocks of forty or fifty. They are seldom seen in the valleys, preferring to keep the summits and sides of the hills, where they feed on mountain-berries and the like. Being generally hatched in April, if the summer has been dry, the young birds will be pretty strong on the wing and ready for the sportsman by the 12th of August.

The best weather for shooting is that which is dry, clear, and warm; wet makes them lie still on the ground. No one need attempt grouse-shooting

who is of delicate health, or not well trained by previous feeding and exercise. Walking over heather is very fatiguing, and the risk of taking cold from rain or wet feet considerable. The dress ought to be very strong; stout shoes or quarter-boots are indispensable.

Partridge-shooting.—Of partridges there are two kinds, the red and gray, the latter being that which is common in this country; the plumage is of a brown and ash colour, elegantly mixed with black; the tail is short, and the figure more plump than handsome. Partridges pair about the third week of February, and sometimes, after being paired, if the weather be severe, they all gather together and form a covey, and are then said to pack. They begin to lay in six weeks after pairing. The female lays her eggs—from twelve to twenty—on the ground, scraping together a few bents and decayed leaves into any small hollow. The young birds begin to appear early in June, and to take the wing towards the latter end of that month. In dry seasons, they are most numerous. So many are the enemies of the partridge, that it is believed never more than a half of those produced come to maturity, and yet there is in general abundance for the sportsman during the shooting-season. The affection of both parents for their young is very remarkable; they lead them out in quest of food, shelter them with their wings, and resort to many tricks to lead supposed enemies away from their broods. Turnip and corn fields are the places which partridges most delight in, especially while the corn is growing; for that is a safe retreat where they remain undisturbed. They frequent the same fields after the corn is cut down, and there feed on the dropped grains, finding a sufficient shelter under cover of the stubble. When the winter comes on, and the stubble-fields are either trodden down or ploughed up, they then retire to the upland meadows, where they lodge in the high grass; they also sometimes resort to the low coppice-woods, especially if they are contiguous to corn-fields.

Partridge-shooting commences on the 1st of September, and ends on the 1st of February. In the course of September, the short flights of the coveys, in tolerably well-preserved grounds, afford abundance of sport. In more open districts of country, where there is a wider range, partridge-shooting requires more skill, and the aid of a steady pointer or setter. In shooting either at a flight of grouse or covey of partridges, select a bird on the outside, and fire at it alone; it is only over-hasty or ill-taught sportsmen who fire at the centre of a covey.

Pheasant-shooting.—Pheasants are a species of birds allied to domestic fowls, and partake of some of their habits; no birds of the game kind possess such elegant plumage, and few are so large. They breed on the ground, and, like partridges, are fond of nestling in clover; but their chief resort is shrubberies or secluded spots in plantations. The pheasant and its brood, if undisturbed, remain in the stubbles and hedgerows some time after corn-harvest; if molested, they seek the woods, and only issue thence to feed in the stubbles at morning and evening. Besides corn, the birds will live on wild-berries, or any seeds they can pick up. As the cold weather comes on, they begin to fly up at sunset into trees, where they roost during the night.

It is necessary, in pheasant-shooting, to use a short double-barrelled gun of wide bore and large shot. Fire at not a greater distance than thirty yards, and only when the bird has risen clear of the bushes; aim is to be taken at the head; but if the pheasant is crossing your path, fire a little before the head, the rapid flight of the animal bringing it in contact with the shot.

GAME.

Though, according to law, wild animals are no one's property, yet only certain kinds may be killed without a licence. Game is defined to include the following animals only—namely, hares, pheasants, partridges, grouse, heath-game, moor-game, black-game, and bustards. The close season applies only to the winged game, so that hares can be lawfully killed all the year round. But no game must be killed on Sundays or Christmas-day; to do so, subjects the offender to a penalty of £5. Though the above animals alone are game, the game-acts also protect certain others—namely, woodcocks, snipes, quails, landrails, and conies; that is to say, any person illegally trespassing in pursuit of these may be fined £2. These game-laws are relics of ancient laws instituted by the Anglo-Saxon and Norman sovereigns for protection of the royal forests.

ANGLING.

The art is so termed from *angle*, a bend, a hook. The practice of taking fish in this excusably crafty manner, either for profit or for amusement, is of great antiquity, as we may learn from the mention made of it by the prophet Isaiah: 'The fishers also shall mourn, and all they that cast angle into the brooks shall lament;' chap. xix. verse 8. This, however, is nothing to the antiquity witnessed to by the fish-hooks made of bone found in Kent's Hole and similar places, and evidently the work of men that lived while England was the home of the hairy elephant and other animals now extinct.

No kind of amusement has been the object of such frequent description as angling. Hundreds of treatises have been written descriptive of the sport in all its departments, and with reference to all varieties of fish and the waters to which they resort. The first writer of note on the subject, and who has been acknowledged the great father of the angle, was Izaak Walton—born at Stafford 1593, died 1683—who in the year 1653 gave to the world his *Complete Angler*, a work which till this day is esteemed not more for the correctness of its details than the singularly happy humour of its apologues, poetical pieces, and disquisitions.

GENERAL CHARACTERISTICS OF FISH.

The fish which are the object of attention to the angler are all confined to fresh water, and are chiefly found in rivers or small brooks; some are found in lakes and ponds. All, except eels, have a pretty uniform character—more fully detailed under the head ZOOLOGY—though differing in appearance and size.

The senses of fish have engaged much attention from naturalists. Their quickest sense is that of

sight; but they are destitute of the power of contracting the iris of the eye, so as to accommodate themselves to different degrees of light. In ordinary circumstances, this is of no consequence, as the water diminishes the intensity of light, and the animal has the means of retiring to the bottom, or into holes, to escape the glare of the mid-day sun. As regards the sense of hearing in fishes, opinions are conflicting; but the senses of taste and smell are largely developed: they are also provided with an appetite of boundless voracity.

'Every aquatic animal that has life,' observes Daniel, 'falls a victim to the indiscriminate voracity of one or other of the fishes. Insects, animalcules, worms, or the spawn of other tenants of the waters, sustain the smaller tribes; which in their turn are pursued by millions larger and more rapacious. A few feed upon mud, aquatic plants, or grains of corn; but the far greater numbers subsist upon animal food alone; and of this they are so ravenous as not to spare those of their own kind.'

It is understood that fishes possess a blunted nervous energy, which renders them almost insensible to any ordinary infliction; and so mean are their reflective faculties, that after escaping from a hook which has lacerated their palate, they will in the next minute catch at a similar bait. Yet, in strange opposition to this is the rapidity with which *river* trout, at least, will discover the deceit in any new scheme or lure devised for their capture, and to all appearance transmit their cunning to posterity.

FISHING-TACKLE.

The equipment of the angler consists mainly of his rods, lines, hooks, and baits, with the means of keeping them in order, or supplying their place in the event of an accident. To these, dealers have added numerous accessories, more cumbrous than useful, and always more sought after by the holiday angler than the genuine disciple of Walton. As one-half the art depends on proper equipment, we shall describe the leading implements in detail.

The Rod.

This is the chief implement of the angler. The wood most suitable is hickory or ash, with yew for the butt. Young anglers are too apt to select rods measuring from twelve to sixteen feet in length for trout-fishing, when in reality a simple, and not too elastic wand of from ten to twelve feet for trout, and from eighteen to twenty feet for salmon, will amply suffice. Whatever be the length, it must be quite straight, and on all occasions bend back to its original straightness. If there be a single knot in the timber, reject it, for it will certainly snap at the first severe pull or jerk. It should be varnished, to protect it from the action of the water. The rod is not all of one piece; for the sake of convenience, it is divided into three, and sometimes as many as six pieces in the length.

The Reel.—It should be as simple as possible in mechanism—the complex invariably go wrong, and so may spoil a day's sport.

Lines.

The part of the line which is wound on the reel, and goes along the rod, is called the *reel-line.* Reel-lines used to be made of horse-hair; they are now preferred made of hair and silk mixed, or of plaited dressed silk. The mixed hair and silk is perhaps preferable for trout-fishing; and eight-plait dressed silk line for salmon. The *weight* of the line should be proportioned to the weight and stiffness of the rod, otherwise it will not cast well. For trout-fishing, thirty or forty yards of line are sufficient; but it is well to have at least 100 yards for salmon, although it is seldom that so much is run out.

The *casting-line* should be made of twisted gut, beginning with three threads and ending with one. It ought to be attached to the reel-line by a splice, whipped with silk. To cast well, it is essential that this line taper from the splice to the end to which the fly or bait line is to be attached. From two to four yards is the proper length. In fishing large clear rivers, a much longer casting-line is required than in fishing streamlets. The *fly* or *bent line* is of single gut. It also should taper from the point at which it is united to the casting-line to the end. It should not be joined to the casting-line by a loop, but by a knot. At least, loops are considered fatal to sport in clear streams by the cunning anglers of the Scottish Lowlands.

Gut.—This material, of such importance to the angler, is prepared from the silkworm at the time when it is just about to spin, and the sericteria or silk vessels are distended with the secretion. The worms are immersed for twelve or fourteen hours in strong vinegar, and then taken separately, and pulled in two very gently. The skilled operator knows at sight if the soaking in vinegar has been sufficient, and if so, he lays hold of one end of the viscid secretion, which is seen in the silk glands, and attaches it to the edge of a board; the other end he stretches to the other edge of the board, and attaches it with a pin. When a number are drawn across the board, it is set in the sun for the threads to dry, when they are tied into bundles for use. They are chiefly produced in Italy and Spain.

Good gut should be round, transparent, and thin. Flat gut glitters in the light; if it has a glossy, milky appearance, it is also conspicuous; and however round and transparent, it will not answer for delicate trout-fishing, unless it is as thin and fine as is compatible with the necessary strength. Of the immense quantity of gut imported, the greater part is of very inferior quality. According to the *Practical Angler* (the late Mr Stewart), 'nine hanks out of ten are totally unfit for fine trouting purposes, and even the very finest hanks seldom contain more than twenty threads fit for dressing flies, or bait hooks upon.'

To deprive gut of the clear glitter which it naturally has, it is usual to stain it of an amber colour, or of a bluish green. Steeping the gut in tea or coffee lees, cold, gives a slight amber discoloration; a deeper tint is given by water in which walnut-shucks have been steeped. An infusion of logwood with a little copperas added gives a bluish green. Diluted ink is objectionable.

In knotting gut, it should be well moistened, to prevent cracking; to keep well, it requires to be moistened with fine oil. A line should never be put away wet. After fishing, as much as has been exposed ought to be drawn off the reel, and thoroughly dried before being wound on again.

Hooks.

These are small instruments made of tempered steel, and of whatever size, they require to possess the qualities of lightness and great strength. If over-tempered, they are brittle, and the angler discovers, after perhaps scratching and missing some fish, that the point of his hook is gone. With too little temper, the hook opens out, and is useless. Try the power of resistance by forcing the bend with the fingers, and urging the point against the thumb-nail. The shape of the bend is a matter of controversy; some advocating the 'round bend' (No. 1), others the Limerick (No. 2), as it is called.

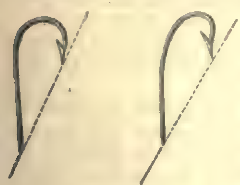


Fig. 3.

Landing-net—Gaff.

The *landing-net* consists of a small bag-net stretched on a hoop at the extremity of a pole four or five feet in length. In Scotland, the landing-net is little used in river-fishing, and is looked upon as more troublesome than profitable. But in lake-fishing it is indispensable, and is often convenient in streams where the banks are steep, or beset with weeds. The meshes should be small enough for catching minnows. Landing-nets can be had that fold up and occupy little room.

The *gaff* is another aid to landing fish, and is employed in cases in which the landing-net would be too small. It is used chiefly for landing salmon, and consists of a peculiarly shaped hook at the end of a staff.

Angler's Pocket-book, &c.

The angler's equipment is completed by the addition of a basket for holding his fish, which is slung on the back by a shoulder-belt; also a pocket-book for holding hooks and other trifles; and a round flat tin box for his fly-casts. Many carry their supply of fly-casts wound round their hat, and some keep them within the leaves of their pocket-book. This pocket-book, which is the storehouse of all kinds of odds and ends—we have seen a good one made out of an old pocket almanac—should have two or three pockets for holding an assortment of hooks, silk thread, stuff for making flies, gut, wax, small cord, fly-nippers, scissors, &c.—all to be used in case of breakage of tackle or rod, or any other accident. In fishing for perch, gudgeons, bream, &c. a small float is often used. Floats are made of cork, quill, reed, and other materials: and a choice, according to circumstances, can be added to the contents of the pocket-book.

Baits.

The materials, living and dead, used for bait are very numerous; but the leading kinds are worms, maggots, minnows, and various insects.

Worms used for bait are of various sorts; but that which is most commonly employed is the lob or garden worm, a long reddish-coloured reptile found in abundance in many gardens, grass-plots, under old cow-droppings in fields, and in any rich old soil. They should be kept in a jar along with moss that has been dipped in water, and squeezed almost dry, in order that they may scour themselves. In three days they will be ready for use. By keeping them in a cool place, and changing the moss or washing it in pure water every day, worms may be preserved for many months. *Fresh* worms, however, are now considered best for salmon. Another worm, which is found in dunghills, called the *brandling*, from its striped appearance, forms a good bait. It is the best when the Stewart tackle is used, as it does not knot or break. It is also the best bait for perch.

Maggots, or the larvæ of insects, as is well known, are found on fly-blown meat or any putrid animal substances: very fine ones are procured from game in a *high* condition. Daniel calls these creatures *gentles*, and describes them as of great virtue in certain kinds of fishing. 'Gentles are so universal and so alluring a bait, that the angler should never be unprovided with them. Trouts have been taken with them in clear water, when they have refused all kinds of worms and artificial flies.'

Caddis, or *cad-bait*, is another kind of larva, inhabiting pieces of straw, or little cylinders formed of bits of stick or sand at the sides of rivers. They are always most deadly in the rivers from which they have been taken, and are found to answer best in tributary streams. 'To collect them, turn up the stones, and the best will adhere to them. When the quantity wanted is obtained, put them into a linen bag for five or six days, dip them, together with the bag, into water once a day, and hang them up; they will then turn yellow, become tough, and fitter for angling than when first got from the brook.'

Minnow bait.—Minnows are a small fish, from an inch to two inches in length. They swim in shoals, and may be captured by a hoop-net on the end of a staff, or more simply, by a crooked pin baited with a small worm. Anglers generally hire a boy to catch a quantity of them. The tackles used for minnow bait are various in their formation.

The most approved minnow tackle consists of two hooks dressed on the same gut, a little apart

Fig. 4.

(fig. 4). In baiting, the large hook is entered at the mouth of the minnow, and brought out a little above the tail, leaving the lower part of the minnow

a little curved, so as to spin when drawn through the water. The upper hook is then stuck through the lips. Some use a triangle appended, as shewn by the dotted line of the fig. The trace or casting line, intervening between the minnow tackle and the reel-line, is of stout gut, and provided with two or more swivels, to allow for the spinning of the minnow.

The tackle for parr-bait is of the same construc-

Fig. 5.

tion as that for minnow. Fig. 5 represents a parr-bait on the hooks.

The perfect insects used for baits are grasshoppers, crickets, day-flies, spring-flies, May-flies, humble-bees, and various others. The ephemeræ, or those fragile creatures that live but for a day, or even a few hours, and therefore called day-flies, are found sporting by the low banks of rivers in warm weather, and form a taking bait for trout and some other fish.

Artificial Flies.

We cannot afford space to describe the making of artificial flies in a way that would be of any practical use. Let the tyro in angling, who wishes to learn to dress flies, begin by taking lessons from a tackle-maker. We will content ourselves with naming a few of the most approved varieties, after having said a few words on the theory of fly-fishing. The prevailing system—in England it may be said to be universal—is what is called the 'entomological,' which goes on the principle 'that, in order to fish successfully, the angler must use an imitation of one or other of the natural insects on the water at the time.' Anglers holding these views have a great variety of flies made to resemble as closely as possible so many real insects. 'They have a fly for the morning, another for noon, and another for the evening of every day in the year, and spend a great deal of time in taking off one fly, because it is a shade too dark, and a second because it is a shade too light, and a third to give place to the imitation of some insect which has just made its appearance on the water.'

From this view, notwithstanding its great apparent reasonableness, many distinguished Scottish anglers dissent both in theory and practice. Let the lure, they say, have a general resemblance to a fly or insect of some kind, either dead or alive, and take care that nothing indicate that it is not natural, and it will take as readily as a more exact copy of a particular species. Fine gut and a small fly are of more consequence than close resemblance. The secret of a small fly is, that the artificiality is less readily perceptible than in a large fly. What Mr Stewart considers it important to imitate is the general shape and the lightness and neatness which characterise river insects: he strongly objects to the ordinary run of flies as too bushy.

Artificial flies are of two kinds—flies, properly so called, with wings; and palmers or hackles, which have no wings, but only a body with fibres projecting all round to represent bristles or legs. They are supposed by some to imitate caterpillars; Mr Stewart thinks they are liker spiders, and gives them that name. He holds that three spiders—the black, the red, and the dun, and three kinds of winged fly, are quite sufficient variety for all purposes of river trout-fishing.

Mr Stoddart, one of our most experienced anglers, says: 'The colours of water and sky are the only indicators which can lead us to select the most killing hook, and even these are often deceptive. We have fished in one stream where dark, and in the next, red flies took the lead. There is no trusting to the fancy in certain places. On Tweed, we have seen it veer about like the wind, in one moment, without a note of preparation. Most rivers, however, are more steady; and when the water is of a moderate size, may be relied on with at most two sorts of flies all the year round. For ourselves, our maximum in every Scottish stream is reduced to only four descriptions of artificial flies, with one or other of which we engage to catch trout over all the kingdom. Knowledge and practice have convinced us of the needlessness of storing up endless and perplexing varieties, which some do, in order to appear knowing and scientific.'

The flies in most general use in river-fishing are the blue dun, known also as the hare's ear or hare's lug; the March brown; the May-fly or green drake; the stone-fly, which is the May-fly of Scotland; the white moth (for evening fishing); and the spiders above mentioned. For lake-fishing, the flies are larger and of brighter colours; the fish lying deeper, require a larger object to attract their attention. Almost every lake has one or more flies peculiar to itself, which are believed to be more effectual than any other. Irish anglers are especially fond of fancy flies of the most gaudy hues.

Salmon Flies.

Of salmon flies the name is legion; Mr Francis devotes nearly a hundred pages of his book to a description of the various hooks used on the chief salmon streams of the United Kingdom. Enthusiasts in the art have bookfuls of specimens, labelled with their local names—the Doctor, the Parson, the Claret, the Blue Ranger, &c. It is a curious fact that, while to be effective in river trout-fishing the fly must be as natural as possible in size and colour, the same rule does not hold either in lake trout-fishing, or in salmon fishing. In the latter especially, something as unnatural as possible would often seem to be the most tempting to the fish. The accompanying figures and description will give a notion of their general appearance and construction.

'No. 1. Tail—crest-feather from golden pheasant; tip—gold tinsel and orange silk, with two turns of ostrich herl; body composed of claret-coloured pigs' wool and mohair mixed, with a little pigs' wool at the head, of a light-blue shade; wound with silver tinsel and dark-red hackle, with blue jay's feather for shoulders; wings—from the teal-duck or widgeon, distinctly marked or barred; head—of black ostrich herl.

'No. 2. Tail—crest feather from golden pheasant; body composed of pigs' wool and mohair

mixed, of a dark-cinnamon shade; wound with silver twist and dark-red hackle; shoulders composed of breast-feather of the argus pheasant; wings composed of golden pheasant tippet or neck feathers, distinctly marked teal, four fibres of blue

Fig. 6.

and red macaw tail-feathers, with pairs of wings from the brown and black barred feathers of the peacock wing surmounting the whole; a blue feather from the kingfisher or blue chatterer on each side of the wings; feelers—from blue and buff macaw tail-feathers; head — black ostrich herl.'

PRACTICE OF ANGLING.

There are two distinct kinds of angling—bait-fishing and fly-fishing, and these are variously practised according to the depth, current, and state of the water, or the nature of the fish sought to be caught.

Bait-fishing.

The mode of fishing with bait differs according as it is practised on sluggish rivers and ponds, or on rapid streams. The fish usually sought for in the deep and somewhat dull rivers of England, are gudgeon, dace, roach, bream, chub, barbel, tench, carp, perch, and pike: all are sometimes taken by fly; but a bait of worms, or gentles, is commonly employed. The angler in these rivers either stands on the shore while fishing, or fishes from a punt, or small flat-bottomed boat, in which he sits watching his float, and pulling in his line when a fish appears to be hooked. The float consists of a piece of cork or a porcupine quill, kept in a perpendicular position on the surface of the water by an exact balance of leaden shot; and is attached to the line at such a distance from the end as to allow the bait to trail slightly on, or just free of the bottom, while the float swims on the surface. Having chosen a spot for his operations, the angler usually baits the bottom of the water, in order to draw the fish together. This ground bait consists of chopped worms, gentles, bran, boiled grains, cheese, &c. It should be made up in balls or pellets, mixed if necessary with marl or clay, so that it may reach the bottom without breaking up. It is well that the 'pitch,' or 'swim,' as it is called, be baited twenty-four hours before being fished, that the fish may have time to become hungry again. If this has been neglected, a few fragments of worms may be scattered over the spot during operations.

The first thing the bait-fisher has to learn is the art of baiting his hooks. Taking the hook in his right hand, and the bait between his fingers in the left, let him enter the hook at the head of the worm, and carry it through the animal to near the tail, covering the entire hook and its tying. The worm should be broken or mangled as little as possible; and the more lifelike it appears, the greater the probability of its proving an effectual lure.

In throwing the line with bait, take care not to splash the water, but throw somewhat horizontally forward, so as to let the bait fall gently on the surface, and sink slowly in the water to the required depth. After sinking, the rod and line should be very slowly moved in a direction against the stream, or in some other way to give motion to the bait, which the fish perceiving to glide through the water, will hasten to seize upon.

Occasionally the angler will *feel* a nibble, but he must not be in a hurry to *strike*—that is, to pull so as to run the hook into the fish's mouth. Perhaps it is no more than a nibble, and it is well to allow the fish time to get the hook in his mouth. If drawn too quickly, you may actually pull away the hook after it is half-gulped. Experience and dexterity are required in this ticklish part of the craft. As a general rule, do not strike till the line has been distinctly tugged; then strike by a slow side-motion at first, then a more quick jerk, so as to cause the hook to catch in the jaws of the animal. Supposing the fish to be hooked, do not draw it violently out of the water, as if in a transport of delight, but wind up part of your loose line if necessary, and holding up your rod, retire gradually backward, by which the fish may be landed on the shore.

The *gudgeon*, a fish of the trout shape, affords a favourite amusement to anglers in the Lea, a river near London, and also in the Thames. Blaine thus speaks of this branch of angling: 'Fishing for gudgeons in the Thames is usually practised by means of a punt, which is fixed across the stream part of the river just above a tolerably sharp *scower*, running over a fine gravelly bottom, free from weeds, at depths varying from five to eight or ten feet. As the eddy is greater, generally, and the water deeper, in these scowers than in those of the Lea, so the tackle used is commonly somewhat stronger, and a fine gut-line is more frequently met with there than one of single hair. Fine tackle, however, in a good hand, is to be always preferred; and we have seen many hundred dozens of gudgeons taken in the sharpest currents of this river also with a single hair only for the two bottom links. Punt-fishing for gudgeon in the Thames is a delightful amusement, particularly to the luxurious angler who is not inclined to take much trouble.'

The *roach* is a thick fish, deep from the back to the belly; it inhabits the bottom of deep rivers or lakes, and is usually reckoned so incautious and silly as to be called the water-sheep; nevertheless, it is not taken without some degree of skill, as is shewn in the *Book of the Roach*, by Greville Fennell (to whom we are indebted for revising the present sketch). It is angled for by means of bait sunk to within a few inches of the bottom.

The fish may be attracted by throwing in some crumbs of bread. It is caught in the Thames some time after the end of August. The baits used are gentles, red paste, and boiled malt or wheat; one grain of the latter is sufficient. Great attention is required to strike quick when the bait is taken. Dace and tench are angled for much in the same manner. Carp is angled for in stagnant waters from February to September, and the baits are worms, larvæ, grain, and pastes. The perch also inhabits dull waters, and is a fish much coveted by epicures, and always fetches a high price in the English market. The baits employed for it are worms, insects, and minnows.

Pike-fishing.

The pike is a voracious fish, and may very appropriately be termed the fresh-water shark; it does not confine itself to feed on worms, insects, fish, and frogs, but will devour water-rats and young ducks, and attack much larger animals. We are told, also, that on one occasion a snipe was found in the stomach of this voracious tyrant. All small fish are terrified at the approach of this marauder, which, if permitted, would soon clear a pond of all its finny tribes. It attains to great age and size. Pike from 10 to 20 lbs. are by no means uncommon, but a fish of 40 lbs. is sometimes heard of, and there are records of 80 lbs. and one even of 170 lbs. The pike is often called the Jack, although that name is properly applied only to young pike up to the weight of 4 lbs. or so. They frequent both lakes and rivers, and generally station themselves in or near beds of weeds, and in corners of bays, and in eddies. They spawn from February till April, retiring for this purpose into backwaters and ditches.

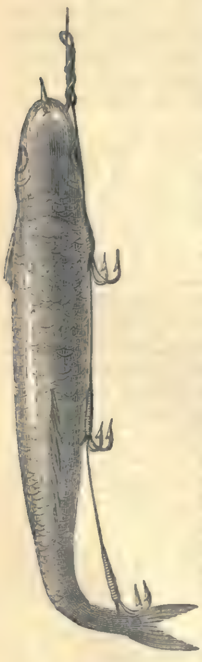


Fig. 7.

There are various ways of catching pike; they are even taken sometimes with large gaudy flies. But the most approved and sportsman method is by spinning with any small fish, such as a gudgeon, a dace, or a small trout for a bait. The tackle is similar to the minnow tackle above described, only that the trace and the gut, or rather gimp, that carries the hooks should be stronger than for trout-fishing. The accompanying figure will give a better notion of the most usual style of a flight of hooks, and the way the bait is put on, than any description. It requires a good deal of practice to cast such a bait to the desirable distance without making an alarming splash. In fishing a stream, it is recommended to cast across and rather down stream than up. The bait is allowed to sink to a greater or less depth, and is then drawn towards the angler, not uniformly, but in successive shoots. In a stream, this makes the bait cross obliquely, and come to the bank below the angler. When a fish is felt, he must be struck, but not rashly. Pike are also taken in weedy waters with the dead gorge, a method termed trolling; but in this case the pike is permitted from five to ten minutes to gorge the bait, and not struck at once, as in spinning.

Trout-fishing.

Trout is a general name for several kinds of fish that are captured with the rod. Thus, there are silvery species that migrate to the sea, and are variously named sea-trout, bull-trout, salmon-trout, or gray trout. But the angler's fish *par excellence* is the common river or yellow trout (*Salmo fario*), which is a constant inhabitant of fresh water, and of which six are taken by the rod for one of any other kind of fish. It abounds in the lakes and streams of Great Britain, and of the temperate and cold regions of the Old World generally; and the common brook-trout of North America is so like the common trout of Britain, that it may be considered as a variety rather than as a distinct species. It is a question among naturalists whether the gillaroo trout of Lough Neagh and the red-fleshed trout of Loch Leven are distinct species, or only varieties produced by peculiarities of the feeding-ground. Trout are found in the smallest rivulets, but it is only in deep streams and lakes, where there is good feeding, that they attain their full size. From 6 to 10 lbs. is a large trout, though a few instances of 20 lbs. and upwards are on record. In most streams a trout of 1 to 1½ lb. is a fine fish, and four to the pound is a good average. In Scotch streams, trout of 1 lb. are very rare indeed. Five or six to the pound is about the average of the angler's 'take' in the Tweed and its tributaries. In the Highlands the trout are, as a usual rule, still smaller.

The two chief ways of angling for trout are, with the fly and with worm-bait. Fly-fishing is most successful in April and May, and again in September; worm-fishing in June and July, when the streams are small and clear, and at any time in the season when the waters are flooded.

Trout-fishing with Fly.—Of all kinds of piscatorial sport, this is the greatest favourite; it is the cleanliest and least troublesome, and is, in fact, angling *par excellence.* The number of flies used varies from one to six, or more; a cast of two or three flies is as effective as any, and is more easily managed than a larger number. The fly at the extreme end is called the *stretcher* or *tail-fly;* the others are called *drop* flies or *droppers* —in Scotland, *bobs.* The distance between the hooks of a cast is two feet more or less; and the droppers should hang from the main line by threads of gut of two or three inches long. There are various ways of attaching them. Loops are objectionable, as being clumsy.

The fly-cast being attached to the casting-line, the next thing the beginner has to learn is to cast the line into the water—an important point. He should practise at first with a line not much longer than his rod, and indeed the best anglers recommend fishing in all circumstances, when it is practicable, with a short line which you can perfectly command. The rod is to be raised over the shoulder with sufficient force to throw the line backward at full length. A slight pause is necessary to allow this to take place, and the transition from the backward motion to the forward is to be made by a slight sweep. The reason of this is,

that if the end of the line doubles back too quickly and at a sharp angle, it cracks like a whip, and the hooks are snapped off. The forward motion of the rod is at first more rapid than the backward, but it should be gradually arrested at an angle of about 45°, so that the line may stretch out at full length in the air, and then fall gently with its own weight on the water. The flies should fall first, and as little more of the line as possible should touch the water. To be able to let the flies drop lightly like natural flies, and at the precise point—known to the skilled angler only—where the trout is feeding, is half the art.

As soon as a trout rises, he should be struck, but very gently; for no sooner has he closed his mouth on the fly, than he discovers the deception, and drops it; and unless the angler, by a pull of the line, runs the hook into his jaws, he is free. Hence the importance of a keen eye to detect the slightest movement in the water, and a tight line which answers at once to the slightest impulse of the rod. It is vain to strike after you have felt a trout, or seen the break on the surface of the water, caused by his turning to go down.

Down or up Stream?—Fishing up stream has decided advantages over the opposite practice. The chief is, that the angler is unseen by the trout, which always lie with their head up stream—in fact, cannot lie otherwise. Another advantage is, that the unfished ground is less disturbed when a fish is hooked, as the angler can more easily prevent it from running upwards than he can from coming downward. Besides all this, the flies when cast up float down with the current in the natural way that a drowned fly does; and this is the only thing they can resemble. It is only at the instant they drop into the water that they can be taken for a live fly, and so far as that goes, fishing down is on a par with fishing up. When a strong wind or other cause makes casting up stream impossible, cast across and rather up, and allow the hooks to float straight down for some way; they are far more deadly thus than when sweeping across the stream.

The golden rule in angling—to neglect which is to render all other skill nugatory—is, to avoid being seen by the fish; hence the angler should keep as far as possible from the water he is fishing, and also at a low level. At a certain low angle, rays of light can neither enter nor issue from the surface of water. Looking straight down into water, or at a moderately high angle, you can see the stones at the bottom, and in such a position a trout sees you; but bring your head down to near the level, and you see only a glittering surface, and you are equally unseen to eyes within the water. The higher, you stand the wider is the range of seeing and being seen. One advantage of wading, over fishing from the bank, is the lower level of the angler's body. Some enthusiasts in the art, in clear weather, approach a stream crawling, and fish in a prostrate position.

Trout-fishing with Worm.—Worm-fishing used to be looked down upon as fit only for schoolboys; but as practised in midsummer, when the waters are small and clear, it requires an amount of art and skill second only to fly-fishing. The best arrangement of hooks is Stewart's tackle, consisting of three or four small hooks tied to one piece of gut, as represented in the figure. A bright, clear worm, of rather small size—from two to three inches long, and of the thickness of a hen's quill—is the best. Two or three feet of fine gut should intervene between the hooks and the stronger part of the casting-line. A longer rod is necessary than in fly-fishing, because, it being impossible to manage a long line properly, additional length of rod is required to keep the angler out of sight of the fish. Fishing up stream is even more important with worm than with fly. In casting, the motion is slower than with the fly, in order not to tear off the worm. The art consists in throwing up stream, and making the bait drop gently and with precision a few inches above a particular spot where you suspect a trout to lie. No more line should be in the water than is necessary to let the worm float down without interference with its natural motion. In using Stewart's tackle, it is best to strike a few seconds after perceiving that the line is arrested in its downward motion; with the ordinary single hook, a little time should be given, as the trout may have hold of the worm quite clear of the point of the hook. It is only in strong currents or deep water that shot or other kind of sinker is necessary.

Fig. 8.

The best months for worm-fishing are June and July; and, as a rule, trout take best in the early part of the day. But in this respect they are most capricious; after taking freely for a time, they will suddenly disappear, and no more be seen for an hour or two—perhaps for the rest of the day. It is in the streams and at the heads of pools, that trout are mostly to be found. At certain times, they frequent the shallow runs where there is barely water to cover them. The angler soon discovers whether they are in the shallows or in the deeper streams. When there is a breeze of wind, even the still parts of a pool may be fished with worm.

Worm-fishing in flooded waters is altogether different from worm-fishing in clear water. It is successful at all times during the angling season. Instead of the streams, the trout are to be sought for in shallow sides of pools, the thin water at the tails of streams, and in the eddies of streams near the edge. It is not a very enticing kind of sport. Fine tackle is of less consequence than in clear-water fishing.

Lake or Loch Fishing is pursued either from the shore or from a boat, and mostly with artificial flies. The flies are usually larger and gaudier than for stream-fishing; but with little wind and clear water, small river-flies are preferable. When a boat is used, it is allowed to drift, broadside on, with the wind, and the line is cast to leewards, and straight out from bow and stern. Two persons usually fish from one boat. Sometimes, when the fish will not rise to the fly when cast, they may be taken by trailing, or trolling, as it is called in Scotland. This consists in rowing the boat at a slow pace, and allowing the flies to drag behind at 40 to 80 yards' distance. Instead of flies, the artificial minnow is much used in trailing. Of this lure there are several kinds, the

two most approved being Brown's Phantom minnow, and the Angell or Devonshire minnow. Even on a day when the trout are rising to the fly, trailing is used in passing from one part of the loch to another.

Salmon-fishing.

Fishing up stream is not recommended in salmon-fishing, but rather across, the fly being allowed to sweep downward and across. The salmon has a peculiar habit, very likely to upset the calculations of beginners: it consists of the ugly practice of running off at a violent speed as soon as he feels himself hooked, darting up the stream, throwing himself several times out of the water, and generally in the end hastening into some sheltered haunt under the banks where he expects to be safe. Great tact is necessary on these occasions, first to give line, and then to keep him from burying himself in these unapproachable nooks.

Leistering is the name usually given to a murderous kind of pastime once pursued by salmon-fishers in Scotland, but now confined to lawless marauders, who kill vast numbers of fish during 'close time.' Armed with *leisters*, or spears with three-barbed prongs, a set of fishers proceed to the river's bank, and there attract the fish by the glare of torches, held over the water by members of the party. When a salmon is discovered, one selects it as his prey, and by a cool but rapid blow transfixes it with his spear. There is an annual close time, during which it is illegal to angle for salmon. The limits vary for different districts, but are mostly from some time in October to the beginning of February. Common trout are not protected by any such law, but they are seldom fished for between September and April.

The Parr.

The parr is a small fish, which is found in great abundance in almost all rivers which are clear, and have a free communication with the sea. It varies in size, of course, according to its age, but seldom reaches a greater length than six inches, and is usually found below that magnitude. It is silvery in appearance, and marked by peculiar bluish bars or marks along the body; while a more nicely forked tail, and one regular row of scarlet spots along the sides, in place of two or three, aid further in distinguishing the parr from the trout, the fish which it most resembles.

Of the actual character of the parr, whether it is an independent species or the fry of salmon, there has been a long-continued controversy, which may now be considered as settled in favour of its being the young of the salmon. On most salmon rivers, anglers are prohibited from catching parr, and ought to be so on all.

FISHPONDS.

Artificial ponds for the rearing of fish and supplying them when wanted for the table, were common in ancient times. The luxurious Romans possessed such preserves, and we learn that one belonging to Lucullus sold after his decease for upwards of £24,000. Comparatively little has been done in modern times in the way of establishing artificial ponds, and those which exist are chiefly to be found in noblemen's preserves. Yet artificial fishponds may, with little or no trouble, be made to yield a large and regular supply of fish, and may be constructed at a most insignificant expense in any piece of low-lying waste ground intersected by a rivulet of pure water.

The fish most suitable for ponds are trout, carp, dace, roach, bream, tench, perch, and minnows. Eels also thrive in ponds. The size of a pond may be from one to twenty acres; but a piece of water of from two to three acres is considered the most convenient dimensions. Of whatever size, the pond must not be overstocked, and it must not be left too long unfished. Fishponds, to be on the most effective scale, should be in a series of two or three, the water running from the one to the other. This will allow means for periodical cleaning, if required, and for having a choice of fish.

FISHERIES.

WHETHER considered with reference to natural history, manual operations, or economical advantages, the fisheries of Great Britain and Ireland form a theme of considerable interest. To the naturalist, the specific characters of the fish, their food, their change of *habitat*, and the seasons at which they reproduce their kind, or become proper objects of capture, are points of attractive inquiry; while to the economist, the finding out of the best modes of capture and curing are matters of great importance. The present sheet offers a brief exposition of a branch of our commerce which is not so well understood as it ought to be, either by the general public or the political economist. A complete view of the fishing interests of Great Britain naturally divides itself into two portions, one comprising the *food*, the other the *oil* fisheries. We devote the largest part of our space to a review of the former branch of our national industry, as being the most important. Recent fisheries exhibitions (Berlin, Norwich, Edinburgh, London) have specially directed public attention to fish, fish-catching, and fish-culture.

I. THE FOOD-FISHERIES.

The fisheries of Great Britain and Ireland are of the greatest importance to the well-being of the people, whether we view them as a source from which may be drawn very large supplies of cheap and nutritious food, or as an outlet for the remunerative investment of capital, and the employment of a large body of the population. Although the development of our fisheries as a means of commerce is of comparatively modern origin, fish has been used as an article of food from the earliest ages. The rude means of capture at one time adopted, when the object was only to satisfy individual wants, have long since been superseded by a machinery of nets and boats capable of capturing the finny tribe in quantities sufficiently numerous to supply in some degree a portion of the food-wants of our rapidly increasing population, and to make our fisheries no mean source of national commerce; and modern enterprise is doing much to increase these supplies, by adding to the power of capture, and sailing to greater distances, in order to find fresh shoals of fish. That there will be an ample demand for the additional fish-food which improved modes of capture may obtain for us, is quite certain, there being an ever-increasing demand for all that can be brought to market.

Fish is a nutritious and generally much esteemed article of diet. It should be cooked as soon as possible after being taken from the water, as it quickly becomes stale. The fish that are whitest and most flaky when boiled, such as turbot, soles, cod, haddock, whiting, and flounders, are easiest to digest; those which abound in oily matter, such as salmon, herrings, and eels, are if more nutritious, not so digestible. As to the relative nutritive properties of fish and other animal food, Professor Brande states that 'when the muscular parts of animals are washed repeatedly in cold water, the fibrinous matter which remains consists chiefly of albumen; and is, in its chemical properties, analogous to the clot of blood.' Muscle yields also a portion of gelatine; and the flesh of oxen and of some other animals affords a peculiar substance, of an aromatic flavour, called by Thenaud *osmazone*. Albumen and gelatine, then, constitute the leading nutritive ingredients in the different kinds of flesh used as food, and it is important to observe that their relative proportions are not very dissimilar in quadrupeds, birds, and fishes, as shewn in the following table. The water was determined by evaporation in a close-covered vessel, or at a temperature below 212°:

100 Parts of Muscle of	Water.	Albumen or Fibrin.	Gelatine.	Total of Nutritive Matter
Mutton	71	22	7	29
Chicken	73	20	7	27
Beef	74	20	6	26
Veal	75	19	6	25
Pork	76	19	5	24
Cod	79	14	7	21
Sole	79	15	6	21
Haddock	82	13	5	18

According to Johnston, fish in general is less fat than flesh meat.

Fish, when *out of season*, are unwholesome and not good: they are said to be sick; but, by a wise provision, the time varies with the different kinds

	Jan.	Feb.	March.	April.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
Brill	S	S	S	S	S	O	O	O	O	S	S	S
Carp	S	S	S	S	S	S	S	S	S	S	S	S
Cockles	S	S	S	S	O	O	O	O	S	S	S	S
Cod	F	S	S	O	O	O	O	O	S	S	S	F
Crabs	O	O	O	S	F	F	F	F	F	O	O	O
Dabs	S	S	S	S	S	S	S	S	O	O	O	O
Dace	F	F	O	O	O	S	S	S	F	F	F	S
Eels	S	S	S	O	O	O	O	S	F	F	F	S
Flounders	S	S	S	O	O	O	O	O	O	S	S	S
Gurnets	O	O	O	O	S	S	S	S	S	O	O	O
Haddocks	F	S	O	O	S	S	S	S	S	F	F	F
Halibut	S	F	F	S	S	F	F	S	S	S	S	S
Herrings	S	O	O	O	S	S	F	F	S	S	S	S
Ling	S	S	S	O	O	O	O	O	S	S	S	S
Lobsters	O	O	O	S	F	F	F	S	S	O	O	O
Mackerel	O	O	O	S	S	S	S	O	O	O	O	O
Mullet	O	O	O	S	S	S	S	O	O	O	O	O
Muscles	S	S	S	S	O	O	O	O	S	S	S	S
Oysters	S	S	F	F	O	O	O	O	S	S	S	S
Plaice	S	O	O	O	S	S	S	S	S	S	S	S
Prawns	O	O	S	F	F	F	F	S	O	O	O	O
Salmon	O	S	S	F	F	F	S	S	O	O	O	O
Shrimps	S	S	S	S	S	O	O	O	S	S	S	S
Skate	F	F	F	F	F	F	S	S	O	O	S	S
Smelts	S	S	S	S	S	O	O	O	O	O	S	S
Soles	S	S	S	S	S	S	S	S	S	S	S	S
Sprats	S	O	O	O	O	O	O	O	O	O	S	S
Thornback	O	O	O	O	O	O	S	S	S	S	S	O
Trout	O	O	O	S	F	F	F	S	O	O	O	O
Turbot	S	S	S	S	S	S	S	S	S	S	S	S
Whitings	F	F	O	O	O	S	S	S	S	F	F	F

S denotes that the Fish is in Season; F, in finest Season: and O, out of Season.

of edible fish, so that some may be had good during every season of the year. Unfortunately

we are only able to obtain certain kinds of fish at the time when they spawn, and at that time all the fat-forming elements of the animal are diverted to the development of the milt or roe.

The preceding table is applicable to the British markets, and will enable purchasers to see at a glance what fish are in season and what kind are out of season, during every month of the year; and also which kinds are best for immediate use.

The fishes which contribute most largely to our commissariat are the herring, cod, haddock, whiting, salmon, sole, turbot, and other flat-fish, one or other of which is in season on some part of the British or Irish coast all the year round; this is especially the case with regard to flat-fish, whilst the salmon and the herring can only be obtained during certain months of the year; but both of these are of great value, and the herring (also the sprat and mackerel) being at times exceedingly plentiful, may on such occasions be bought cheap, forming an excellent variety in the food of the people. The salmon being a valuable proprietary fish, is, on the average of the period during which it is in season, much dearer than butcher-meat, seldom costing less than one shilling and sixpence per pound-weight, while at certain times it is very much dearer, as much as half a guinea a pound-weight being paid in the early part of the year. It is much to be regretted that fish, when they become reduced in price, are only cheap at most uncertain times, and consequently no reliance can be placed on a continuous supply being brought to market as an auxiliary article of food. The railways now so equalise our supplies, by running each day's catch with great celerity into distant inland towns, as to forbid the idea of fish ever again being cheap, in the old sense of the word. The supply is evidently more limited than the public are willing to believe: at anyrate, with large additions to the varied machinery of capture, our fish supplies do not come up to the daily demand, except on the occasion of an extraordinary catch, when the market is glutted. This will be better seen from the economic details which we are able to furnish with regard to the different branches of the British fisheries.

I. THE WHITE-FISH FISHERIES.

Under this term is included not only the fishery of the common cod, but that of the haddock, whiting, ling, hake, torsk, and others—all remarkable for their excellence of flesh, which is white and firm, separates readily into flakes, is agreeable to the taste, and very wholesome. They belong to the soft-finned fishes, and constitute a useful family of great extent, known as the *Gadidæ*, found in almost every sea, and living for the most part in cold or temperate climates. From their size, and tendency to congregate in particular localities, as well as from the value of their flesh, they are of great importance to man. As our space will not permit us to notice individually the members of this extensive family, we shall direct attention chiefly to the cod, as the head and representative—premising that the modes of capture, curing, and preparation, are much the same as regards the other members of the family; the natural habits of the other families are also similar to those of the cod.

The great seat of the cod-fishery is at Newfoundland and other places on the coasts of North America, and the trade there is mostly in the hands of the French and Americans. Vast quantities of this fish are caught, and are constantly imported into this country dried or cured, constituting a well-known article of commerce. Indeed, so great has become the drain on the cod-banks of Newfoundland, that the supply is, year by year, becoming perceptibly less. In Great Britain, the chief seat of the cod and ling fishery is in the north of Scotland, although supplies are also obtained from the coast of Ireland, and likewise on some parts of the English coast. The cod-fish is very voracious; a favourable circumstance for the fishermen, who experience little difficulty in taking them with almost any bait, whenever a favourable locality is found. As these fish generally inhabit deep water—from twenty-five to forty, and even fifty fathoms—and feed near the ground on various small fish, worms, crustacea, and testacea, their capture is only attempted with lines and hooks. The most common mode is by deep-sea lines, called *bulters* on the Cornish coast: these are long lines, with hooks fastened at regular distances along their whole length, by shorter and smaller cords called *snoods*. The snoods are six feet long each, and placed on the long line twelve feet from each other, to prevent the hooks from becoming entangled. The line has an anchor or grapple and a buoy at each end; it is laid, or *shot*, across the direction of the tide, and after being left for about six hours, it is hauled up for examination.

The fishermen, when not engaged in shooting, hauling, or rebaiting the lines, fish with hand-lines, armed with two hooks, kept apart by a strong piece of wire. Each fisherman manages two lines, holding one line in each hand; a heavy weight is attached to the lower end of the line, not far from the hooks, to keep the bait near the ground.

Vessels sail as far as Davis' Strait and to the Faröe Islands for fresh cod, and quantities are carried alive in welled smacks to London. Boats of this kind, for preserving alive the fish taken at sea, came into use in this country early in the last century. They are said to have been first built at Harwich, in 1712, by an ancestor of the late Mr Saunders of Billingsgate; and it is remarkable that some of them were engaged in conveying troops at the time of the rebellion of 1715. The store-boats remain in the salt-water, and the fish are sent to London and other cities by railway train as they are required.

A considerable number of the cod which are caught on our shores are brought to market as cured fish, and the process of curing is as follows: The fish are usually killed and cleaned as soon as taken. When brought on shore, they are opened up from head to tail, part of the backbone being cut out. They are then carefully washed and purified from blood by copious libations of clean salt-water. Being drained, which is the next process, they are laid down in a long vat, in alternate rows of fish and salt, under heavy weights, to keep them within the action of the pickle. After a time, they are taken out of the vat, again washed and brushed, and gathered into little heaps to drain. This being effected, they are spread out individually to *pine* by exposure to the sun and air. Next, they are built into heaps called *steeples*,

to await the appearance of what is technically called the *bloom*, a whitish substance which comes out on the fish. This completes the business. In Yorkshire, the curers improve on this plan by placing the fish on wooden erections made of cross-bars, which admits of their drying much sooner, keeps them cleaner, and obviates numerous accidents which occur to those dried on the ground.

Statistics of the cod, hake, and ling fisheries are regularly taken in Scotland, but the figures are not trustworthy as giving any idea whatever of the total quantities of these fish taken in the seas of the United Kingdom. The cod-fish has of late years become in great esteem as a luxury of the table, and a guinea has often been paid in London about Christmas-time for a cod-fish of ten pound-weight. At certain times, excellent cod-fish can be obtained at threepence per pound. Although the cod-fisheries can never be expected to be so productive, or to give employment to so many men, as the herring-fisheries, they are highly valuable: the fishery already continues during seven months of the year, and, by a study of localities, might be prolonged for other two months.

Small as our supplies of cod-fish are thought to be, it has been calculated that from our home fisheries alone we annually obtain seven millions of these fish! The cod-fish is likewise found in very large quantities in the Irish bays; and the coasts of Norway, we are told, absolutely swarm with members of the cod family, as we know that profitable fisheries are carried on in the various fiords. This fish is usually referred to as one of the most remarkable instances of animal fertility—the eggs in one female were found to amount to the incredible number of 9,384,000. All fishes are very fecund, and they would require to be so, as vast numbers of their eggs never come to maturity, and thousands of the fish that may come to light are devoured by enemies. It is questionable if thirty per cent. of the eggs of any sea-fish ever come to life, or if five of the eggs of each thirty that do fructify come to market as fish fit for the table. Cuvier says that 'the flesh of these fishes, which is white, firm, and of most excellent flavour, renders them exceedingly valuable to us. It is capable of being preserved in a state fit for eating much longer than that of other species of this class. Its consumption is consequently extended through the four quarters of the globe.'

There is a large commerce carried on in other members of the cod family, chiefly, however, in whitings and haddocks, which are much esteemed when fresh, as also when dried and brought to market, as the well-known Finnans. The haddock is now becoming rather scarce, but is still found in large numbers in the British seas, and is taken, like the cod, chiefly by baited lines; considerable quantities are also got by the use of trawl-nets in the deep-sea fisheries. It is supposed that the very finest are to be found in the inlets and bays of the sister-island. The fish used at one time to be smoked or cured in a very simple way by most of the inhabitants of our fishing-villages. After being split up, the intestines were taken out, and the fish was then hung up in the chimney-corner to be smoked, generally by means of a peat-fire; as many as two hundred being made ready in a batch at a fire-side of ordinary size. Finnans are now 'manufactured' more systematically, being smoked in houses built for the purpose. The commerce in this description of fish has greatly increased in Scotland, many having embarked in it on a large scale, purchasing haddocks from numerous captors, who confine themselves almost solely to this department of fishing. The whole process takes only a few hours; so that fish caught in the afternoon may be in a market many miles distant on the morning of the following day. Real Finnans are generally small, and of a pleasant pale-yellow colour; but larger fish (young cod-fish sometimes) are cured at great commercial stations, and in a way intended to admit of their being sent to a longer distance, and keeping for a longer time. The Scottish markets used to have large supplies of the haddock; the quantity taken was sometimes immense; and hundreds of people found a livelihood in hawking that fine fish about the streets. It is now sold at much higher prices than formerly. In 1884, there were taken in the Scottish seas, 464,049 cwts. of haddock, valued at £300,712.

II. THE HERRING-FISHERY.

The herring-fishery is not only important, in the sense of being a large industry forming a good outlet for capital, and a great field for individual and co-operative energy, but it is at the same time picturesque and suggestive, giving scope to the naturalist for speculation, and taxing the brain of the economist in ever-recurring calculations as to the best modes of conducting the fishery, managing the cure, and carrying on the necessary commerce. This fishery has for a long period been a source of wealth to Great Britain, and particularly to Scotland. Of this fact there is abundant evidence in ancient acts of parliament, and in various other historical documents; whilst, in the carefully compiled statistics of the Board of Fisheries, we yearly obtain a tolerably correct notion whether the supply is keeping pace with the ever-increasing machinery of capture, or whether, as has been suggested, the economy of some of the great shoals is so deranged by miraculous annual draughts, as to induce the conclusion that the herring is becoming less plentiful than the public believe.

The most important British herring-fisheries are carried on in Scotland at Dunbar, Anstruther, Peterhead, Fraserburgh, and notably at Wick, which may be styled the herring capital of Scotland; indeed, that town owes its existence to the herring-fishery; in fact, the popular saying of being founded on herring-bones is as applicable to Wick, as to Amsterdam. It possesses a large population, all engaged more or less in fishing; and the capital represented by boats and nets amounts to a very large sum of money. During some seasons, as many as one thousand boats meet at this port, and as each boat requires four or five persons to conduct its operations, the resident population is largely augmented; and as, on one or two mornings of the season, each of the thousand boats will bring ashore a large quantity of fish, the town wakens into immense activity, not lasting, but intense for the time being. The greater part of the fish taken at Wick are cured for exportation—a trade requiring a large amount of tonnage, and upwards of 1000 men to carry it on. The gutting and packing, also, give

employment to a great many persons, chiefly women, as well as to a number of boats which convey salt from Liverpool, and likewise from foreign ports. There is also an important herring fishery at Yarmouth, a large portion of the catch being cured and sent to market as 'bloaters.' The pilchard (an important member of the herring family) is chiefly caught on the coasts of Cornwall; and the sprat is obtained in large quantities both in Scotland and England.

The herring family embraces the common herring, the pilchard, the sprat, white-bait, and the anchovy, and there is as much mystery attending the natural history of some members of this family, as, fifty years ago, puzzled naturalists in regard to the birth and growth of the salmon. Even in the nineteenth century, there are persons who have not entirely got over the ancient and once popular belief of the herring being a native of the great arctic seas, and instinctively rushing, at the proper season, in vast shoals to these islands, in order to be captured and become the food of man. Naturalists, however, know so much now of the habits of this fish as to be able to refute the old theory, and to state with certainty that it spawns upon our own coasts, where it is 'native and to the manner born;' but where it proceeds to, after accomplishing this process, is somewhat doubtful. Some naturalists aver that the herring never leaves our own seas, but that, after the season of spawning is over, it merely retires from the shores into deep water; and they also assert that shoals aggregate and segregate. There are many interesting points of herring-life not yet understood: it is not known, for instance, how long the spawn takes to come to life, or the rate at which the animal grows, or at what period it becomes reproductive, and there has been much controversy on these points of its natural history.

The herring-fishery, when pursued on a large scale, is carried on by means of what are called *drift-nets*, the meshes of which are regulated to an inch in size by act of parliament. A single net is generally about fifty feet long, and from thirty to thirty-five feet in depth, and the cost of it is from £4 to £5. For the purpose of capturing the fish, the various nets are joined together into what is termed a *train*, which may run to any length, but is usually from 1500 to 2000 yards—long trains being preferred to short ones. The whole is held in position by the *back-rope*, a strong cord running along the back of the train, and which has fixed to it the buoys, which keep the netting afloat. The train is held down by means of weights. The boats necessary for carrying such a load of netting, it is obvious, must be of considerable value; the best class of them costing upwards of £100. During late years, herring-boats in Scotland have been greatly improved in size and build.

The boats arrive at the proposed fishing-place in the evening; the nets are *shot* after sunset, as the fish always strike best in the dark; and the catch takes place throughout the night. The process of throwing a train of nets into the sea is quite simple: it is *paid* over the stern of the boat, which is slowly rowed over the part of the sea selected as being most likely to be near the shoal. When all the nets forming a train have been shot, a rope about twenty fathoms long, which is technically called the *swing-rope*, keeps the last one attached to the boat. Sometimes the other end of the train of nets is fastened to an anchor, or it may be to the shore, when convenient; but more generally the whole length is only fastened by the swing-rope to the boat, and is allowed to float slowly along, carried away by the tide or current—a great perforated wall, 2000 feet long, and 24 feet deep, standing upright in the water. When the shoal, in its progress, comes against this barrier, the fish are caught by what is called *meshing*—that is, by thrusting their heads through the interstices of the net, and being entangled by their gills. Sometimes the fish have to be waited for long, and perhaps none may be got for a whole night; at other times a heavy take may occur in less than an hour. To ascertain whether or not the fish may have struck, a custom exists of *preeing* the nets—that is, lifting out a portion of a train and examining it. If there be no appearance of fish, the labour of hauling in, removing to a new spot, and again shooting, has to be undergone, in the hope of being at last lucky. Supposing the fish to have come upon the train of nets, the process of hauling into the boats and taking the herring out of the meshes, is commenced. Formerly, it used to be the practice just to haul in the net, and leave the fish sticking in it by the gills till the boat landed; now, as the nets are hauled on board, the herrings are carefully shaken out, a decided improvement on the old plan, which frequently mutilated the fish very seriously.

The proper cure of the herrings has at all times occupied great attention, and Dutch fishermen are said to excel in the art. The quantities cured by the Dutch, however, are small, as they cure them on board their fishing-luggers, where the number of persons is limited. In Scotland, the curing is chiefly done on shore, and it is a general rule that the fish brought to the quays in the morning *must be cured that day;* and on some days as many as twenty thousand crans have been brought on shore at the port of Wick.

The fish are carried to huge but shallow gutting-tubs prepared for them. They are then operated upon by a band of females, who gut them with extraordinary rapidity. One thousand fish an hour being common work, it may be readily conceived that, when a large number of hands are employed, an immense shoal can be disposed of in a few hours. The women employed usually work together in little bands of four or five, each performing part of the labour which is necessary, some carrying, some salting. After the fish are eviscerated, which is rapidly performed by two simple movements with a knife, they are transferred to another vat or trough, where they are laid down in layers of salt. The sooner the herrings are sprinkled with salt, the better will be the *cure*. Then they are *roused*, as it is called—that is, a stick or a brawny arm mixes them well together—a process repeated at intervals till the trough is filled. After a brief rest, depending much on circumstances as to its length, the herrings are carefully re-sorted, and then packed into barrels, either flat on their sides—to suit the Irish market—or backs downward, to please the foreigners. Every row, as it is put in, is well sprinkled with salt. A week's rest is allowed before the barrels are finally headed up, as the fish settle down so much as to admit of an additional quantity being put in.

Formerly, almost the whole 'take' of herrings in

Scotland—that is, of cured herrings—was branded by the government fishery officials, in token of fish being full of spawn, and all the curing operations having been complied with. The brand is now a voluntary certificate, for which a small fee is exacted, and a considerable number of barrels are annually disposed of without that mark of merit.

Statistics of the herring-fishery are annually collected in Scotland, so far, at least, as to ascertain, with tolerable accuracy, the quantity of these fish which are 'cured' at the various accredited fishing-ports. The quantity of fresh herrings which are despatched by railway is enormous. A train filled with herrings, leaving Dunbar in the morning, can easily reach Manchester the same day. Of the 'cured' fish we have the following official statistics of the take in recent years: (1868) 638,260 barrels; (1869) 675,143; (1870) 833,160; (1871) 825,475; (1872) 773,859 barrels. The 'take' in 1880 was the greatest on record up to that time, but was much exceeded by that for 1884; the value of cured herrings in that year being £2,121,346, while that of herrings sold fresh was £150,720. The number of barrels cured in that year was 1,697,077, as many as 653,425 having been branded. The number of boats engaged in the herring-fishery, as well as the quantity of netting employed, has been largely increased during the last forty years, but the take of fish has not been commensurate—hence a cry has arisen from some economists that the herring is being 'over-fished.' The chief moving power of the Scottish herring-fishery is the curer: he it is who sets the whole trade in motion; he engages the boats, paying so much money by way of premium when he does so, and giving a fixed sum to its owner per *cran* (the *cran* is a measure which contains forty-five gallons of ungutted herrings), for his catch during the season; the bargain is usually for two hundred crans, and, as a rule, only a few of the boats obtain this number. The curer provides, of course, all the materials of the cure; he engages coopers to make the barrels and superintend the packing of the fish; also the women whose duty it is to eviscerate them. Some of the Scottish herring-curers have been very enterprising men, notably the Methuens, who in some seasons had as many as 10,000 people in their employment. These gentlemen cured at upwards of fifty stations in England, Scotland, and Ireland, and their turnover in connection with this one branch of commerce was usually over £500,000 per annum. It is obvious that if one firm did so much business, the total herring-commerce of the three kingdoms must represent a very large sum of money. The following summary of the number of persons employed in the herring-fishery in Scotland, the number of boats engaged, their value, and the value of the netting, is from an official return, and may be relied upon as being tolerably accurate.

The number of boats in 1884 was 15,445, and in the same year 49,860 men and boys were required to man them. These boats and men were employed by 1062 fish-curers, who required 2809 coopers and 48,832 other persons to oversee the cure. Thus it may be safely said that about half a million persons, or nearly one-seventh of the entire population of Scotland, are dependent on its fisheries. The money value of the boats and nets is set down at £1,802,886. It is difficult to obtain a correct idea of the number and value of the boats engaged in the English herring-fisheries at the Isle of Man, Great Yarmouth, Cullercoats, and other places. M'Culloch estimated the capital invested at Yarmouth and Lowestoft at a quarter million sterling. This latter place employs about seventy boats, of forty tons each. The greater number of the herrings taken at Yarmouth and other places are cured, and known in London and throughout England by the names of 'Yarmouth bloaters,' 'Straitsmen,' 'Reds,' and 'Blacks' for home use. It may likewise be mentioned that Hastings and Folkestone on the English coast have capital herring-fisheries, and that a large portion of the fresh fish which reaches the metropolis is sent from these towns; herrings are also caught in Cardigan and Swansea bays. The Irish herring-fisheries are not worked as they ought to be; hence Ireland, although its coasts abound with fine fish, derives the chief portion of its herring supply from the north of Scotland. When it is taken into account that this wealth is drawn direct from the sea—that no rent is paid for the fishing-grounds, and that no capital is expended in brood-stock or for food to the animals—the value of this item of our national resources is obvious; and the question raised by some, whether we are not by bad economy allowing it to be dried up at its source, becomes serious. The sea is free to all, and there are men who would rob the mighty waters at one fell swoop, if they could, of all their treasures, and not leave within them one fish to breed from.

III. THE PILCHARD AND SPRAT FISHERIES.

The pilchard-fishery is of as much importance to the people at the Land's End, as the common herring is to the people on the north-east coast of Scotland. The pilchard is not unlike the herring, and was at one time caught in the principal Scottish estuaries. Up to the year 1816, it used to be taken in great quantities in the Firth of Forth. At the present time, the principal resort of this fish is the coast of Cornwall, where its capture gives employment to a large number of people, and a considerable amount of capital is required to carry it on.

No exact statistics of the quantity of pilchards annually caught can be obtained, as in the case of the herring, but it is said that of late years the number captured has not been so great as it was at one time—that good old time when 10,000 hogsheads of these fish (each hogshead numbering 2700 pilchards) were seined in one day off St Ives. A common enough haul consists of four or five thousand fish, and it is seldom that greater numbers are obtained at one time; but on one memorable occasion so many pilchards were inclosed in a seine that it took a fortnight to bring them ashore! The mode of capturing the pilchard is, as a rule, different from that of taking the herring, most of them being caught by means of what is called a seine-net; a few are, however, taken by drift-nets. Seine-fishing is novel, and very picturesque, and the fish taken in this manner bring the highest price in the foreign markets. A seine, with the necessary boats, grapnels, and gear, costs about £1500. From the

amount of outlay required, they are generally the property of capitalists, but are sometimes held by a company, 'the concern,' as it is called, being divided into small shares. Twenty men are employed on each seine, who are paid by small wages—generally eight shillings a week—and a share in the profits. The seine measures in length 220, and in depth from 16 to 18 fathoms. On one edge are placed corks, and at the other, leaden weights; and this enormous net is carried in a large boat or lighter, and thrown overboard, so as to encircle a shoal of fish when they can be found in water not deeper than the seine. As soon as the fish are surrounded by this hempen wall, anchors are carried away from different parts of the seine, and it is safely moored; and unless stormy weather comes on, the fish may be kept there, and taken out at leisure; they do not choke, as the herring do in the drift-nets. At Mevagissey, on one occasion, when salt became scarce, the seines were left in the water, and the fish kept alive till a vessel went to Normandy and brought back a cargo of salt. The fish are lifted out of the inclosed space with a smaller net, called the *tuck-seine*. This is done at low-water and at night, as the fish during the day remain near the bottom, and any attempt at raising them would result in the tearing of the net. *Tucking*, or lifting out the fish, is thus accomplished: The boats in which the fish are to be carried are brought close to the seine, and the small net is drawn tight; two men sit on the gunwale, and with a two-handled basket lift the fish and pour them into the boat. The strange silvery light caused by the living mass of fish; the joy of the fishermen, which breaks out every now and then into songs and shouts, which are echoed by the watchers and other on-lookers from the bold cliffs in the vicinity, make this part of the operation beautiful and interesting. A shoal of fish changes the colour of the water; and this is observed most easily an hour before sunset, at which time the seiners are all silent, and intently watching the water. Much depends upon the eye and judgment of the master-seiner, who accompanies the larger boats in a small boat called the *lurcher*. Great pains are taken to find out when the fish come inshore; and as the season, which is in August and September, approaches, there is much preparation for the work in the Cornwall fishing-villages. By-and-by, the 'hirers' or watchers go out and walk the cliffs, in order to signal to the fishermen the position of a shoal the moment they can descry it.

The following is the mode of dealing with the fish after they are captured. When intended for exportation, they are carried into cellars and *bulked*—that is, laid in rows in a heap, with a layer of salt between each layer of fish. After lying in the salt for a month, they are washed and packed in casks; but before the casks are *headed*, the fish are pressed down, the casks are then filled up, and again pressed; and after being a third time submitted to pressure, the casks are closed up, and considered ready for shipment. The fish being so pressed, keep much better in the warm climate to which they are sent, and a large quantity of valuable oil is produced. It is calculated that fifteen hogsheads of pilchards produce a hogshead of oil, and the produce of this oil adds considerably to the value of the pilchard-fishery, as it yields a large sum; and the scum, or garbage, as it is called, which rises to the surface in the washing-troughs, is purchased by the soap-manufacturers at a remunerative price. The quantity of salt required is very considerable—eight bushels to every hogshead of fish—but the undissolved salt, which is more than half the quantity used, can be sold readily for manure. A good year's fishing returns large profit to the curers, and supplies cheap food and well-paid work to those engaged in it.

The Sprat-fishery is important. It takes place during the winter season, and adds largely to the poor man's commissariat. As will be seen from our table, the sprat is in season for about three months—the fishing commencing in November. The greatest quantities are caught on very dark or foggy nights, when many thousand tons are sometimes taken. The value of those captured in Scotland has been estimated at from seven to ten thousand pounds per annum. In Scotland, the sprat is known as 'the garvie,' from the place where large numbers of it are caught. Sprats are taken much in the same way as herring or pilchards, as also by means of very fine bag-nets. Large quantities of the sprat are also captured on the English coasts—enormous numbers of which reach Billingsgate, and are distributed by costermongers all over London as if by magic—no telegraph laid down to the courts and alleys of the great metropolis could make the fact known any sooner. The mode of distributing sprats by means of the railway is a sure preventive of what happened occasionally some forty years ago—namely, the selling of the over-abundant supplies for manure.

Countless quantities of the sprat are cured in oil, and sent out in lead boxes as sardines—the real sardine being, it may be observed, a very scarce fish. The French fishermen capture their sardines (sprats ?) by means of ground-bait (cod-roe), which is brought from Norway. At Concarneau, on the coast of Brittany, an immense *cure* of sprats is carried on—so extensive that it employs 2500 boats and 11,000 fishermen. A large portion of the fish taken are cured as sardines, being boiled in oil, and sent all over the country in neatly designed metal caskets.

The White-bait is a member of the herring family. It is a very small fish, of silvery lustre, and is plentifully found in the brackish waters of the Thames during the months of summer. It is also found in the river Hamble, which flows into Southampton Water, and it can be taken between Queensferry and Kincardine on the sprat-grounds of the Firth of Forth in great quantities. White-bait dinners are in much repute amongst the wealthier classes of London, who resort to Greenwich or Blackwall, to enjoy the fish in its finest condition. Pennant says of this fish: 'They are esteemed very delicious when fried with fine flour. They come into season about March or April.' The white-bait as supplied in London taverns is a hodge-podge of all kinds of small fish, such as minnows, young bleak, infantile sprats, and the fry of other fish. There have been many interesting controversies about the white-bait, some writers contending that it is a distinct fish, others saying it is an independent member of the herring family. Pennant held that white-bait was the young of the bleak. Donovan said it was the young of the

shad. Of late years, however, it has been pretty well determined that the white-bait is the young of the herring or the sprat. It is necessary to couple the two fish, because large quantities of white-bait have serrated bellies the same as the sprat, whilst others have not; and it is said that the sprat cannot be the young of the herring because of its serrated belly. At one period, white-bait was not so much esteemed as at present. When Pennant wrote, it was eaten only by 'common people' and 'the lower order of epicures.'

IV. THE FLAT-FISH AND MACKEREL FISHERIES.

It would not be any exaggeration to say that the turbot is the most costly fish that comes to the table. The family to which the turbot belongs is called the *Pleuronectidæ*, and it includes also the sole, the halibut, the brill, the dace, the plaice, and the dab. Flat-fish are captured chiefly on the English coasts, and largely on the coasts of Holland, the instrument employed being a trawl-net. Trawling is a very simple way of fishing, and well adapted for the taking of flat-fish, which are mostly denizens of the deeper parts of our seas. The net employed in this method of fishing is in the form of a large bag open at one end. It is suspended from the stern of the fishing-lugger, which drags it at a slow pace over the fishing-banks.

We are indebted to the industrious Hollanders for a portion of our flat-fish supply. The Dutch fisheries begin early in the spring season; and neither the Scotch nor English pursue the fishery with the same success as our enterprising neighbours from Holland. As the year advances, the fish are found in deeper water, where the line must be resorted to. The fishery terminates about the beginning of autumn. The coasts of Devonshire, and off Dover towards the French side, are all productive places for the taking of these kinds of fish. Soles have been caught of the great weight of nine pounds, and very frequently of five pound-weight. Skate-fishing, which is much followed in the north, is similar to the other kinds of trawl-fishing. The skate, however, belongs to a distinct family—the Rays. 'In the Firth of Forth,' according to Dr Parnell, 'these fishes are met with in great numbers, particularly in the neighbourhood of the Bass and May, where they are taken in nets, and are often found on lines set in deep water for cod.'

The commerce in all kinds of flat-fish is very considerable, as may be inferred from the fact, that in one year as many as fifty million pair of soles have passed through the great market of Billingsgate; and plentiful supplies reach London without being enumerated. The turbot supply of the same year was 2500 tons; as much as £120,000 have been paid to the Dutch in one year for turbot. Of dabs and flounders, 112,000 pound-weight are recorded as used in the great metropolis alone. The flounder is a plentiful fish; it is said that about one hundred millions of dab and plaice are consumed annually in London. It is recorded that three millions of flounders were once taken on the coast of Denmark, and that it took a large body of men two or three weeks to secure them. We may judge from these figures of the quantities consumed by the busy populations of those other large towns which are fortunate enough to procure the luxury of fresh fish.

It is astonishing, notwithstanding the number of years we have trafficked in these flat-fish, how little we know of their natural history, the periods at which they spawn, how long it is before the spawn quickens into life, or when the fish becomes reproductive. The turbot has a social history. It was the favourite fish of the historical epicures, although some writers say it was the brill which earned the praise of the classic poets. The very large turbot that we read about as once being common—fish of from twenty to seventy pound-weight—are never seen now; and we suspect that the great fish alluded to—one of 190 pound-weight in particular—were halibut.

It is right to note that trawl-fishing is a most wasteful mode of capture, as the gigantic apparatus kills and 'hashes' more fish than it captures, besides turning up beds of spawn, and destroying the feeding-grounds of the fish. It is difficult, however, to point out any other mode by which such ground-fish could be trapped.

The chief places of the mackerel-fishery are on the English coast, although a good many of this fine fish are now taken on the coasts of Scotland and Ireland. Great Yarmouth, already alluded to in our account of the herring-fishery, is noted for the large supplies of mackerel which it sends to market. The prosperity of this town has chiefly arisen from its fisheries. When the fishing-luggers come ashore with their cargo, it is at once disposed of by auction, and despatched in all haste to London, where, of course, there is a ready market for any quantity of fish. It is a study in mackerel-fishing to have the fish in the market with the greatest possible celerity: to achieve this result, several fishermen will join into a company, and what is taken by the united fleet of boats in an hour or two, is sent off in one of them to the shore, in order to catch a convenient train.

The mackerel is a voracious feeder, and its growth rapid; but the largest fish are not accounted best for the table. Those taken in May or June are considered superior in flavour to such as are caught either in early spring or in autumn. The mackerel spawns in June; and 540,000 ova are said to have been counted in one female.

The modes of taking this fish are, in general, the same as those employed in the herring-fishery, varied by the two other methods which are thus described by Mr Couch: 'The one by means of a long deep net, with small meshes, by which the fish are surrounded, and then either taken from the water by *flaskets*, or hauled direct to the land, in the manner of a ground-net; the other by means of a hook and line, called *trailing*.' The latter forms a first-rate marine sport, and is thus performed: The mackerel will bite at any bait that is used to take the smaller kinds of fish; but preference is given to what resembles a living and active prey, which is imitated by what is termed a *lask*—a long slice cut from the side of one of its own kind, near the tail. It is found also that a slip of red leather or piece of scarlet cloth will commonly succeed. The boat is placed under sail, and a smart breeze is considered favourable; hence termed a 'mackerel breeze.' The line is short, but weighed down with a heavy plummet; and in this manner, when these fish are plentiful, two men may capture from five hundred to a thousand a day.

A large number of what we may call 'fancy fish' are now brought to market, that fifty years ago would not have been taken by fishermen—such as the red and gray mullet, a delicious fish, more especially the red variety; the eel, in which there is a very large commerce; and many others; indeed, so great is now the demand for sea-produce of all kinds, that we should not be surprised to find a good market for the dog-fish, which, at certain seasons of the year, notably during the herring-fishing, literally swarm on the Scottish sea-board. With the excellent cat-fish we are becoming familiar; it is frequently served at fish-dinners as the 'John Dory,' and is set down as the *bonne bouche* of the banquet!

V. THE SALMON-FISHERIES: ANGLERS' FISHES.

The salmon, a fish of great individual value, has long been esteemed a luxury of the table; and being, in a sense, the private property of persons fortunate enough to be owners of a salmon river, or part of one, it has been specially legislated for, and is well protected by acts of parliament passed to determine at what seasons it should be fished for, and during what periods it should be left in peace to repeat the story of its birth, a 'close time' being essential for the preservation of the breed. At one period, the salmon was a plentiful fish throughout the United Kingdom, and in Ireland as well, and was retailed to all who were pleased to purchase, at the rate of from a penny to threepence per pound-weight. It is, however, about half a century since such prices were current: the opening up of the London markets, and even those of continental cities, consequent upon the introduction of steam-transport, very speedily raised the price of salmon to a rate which prohibited all but very wealthy people from purchasing it. A common enough price for this fish is half a crown per pound-weight for fine cuts; but early in the season, when the rivers are opening, ten shillings a pound-weight can be obtained in the West-end fish-shops of London. Thus, a salmon of ten or twelve pound-weight, which has cost its proprietor nothing for food, is at some periods of the year of far more value than a sheep reared at considerable expense, from parents which cost a large sum of money. The high price obtained for this fine fish in the English markets induced over-fishing, and, as a consequence, the breeding-stock was broken in upon, and the economy of many of the best rivers deranged. As Lord Polwarth said, eighteen years ago, when addressing a meeting of salmon lairds: 'You are living upon principal and interest, a system which would speedily ruin any property.'

The salmon is, more than any other fish, a victim to the depredations of pirates of all kinds. The spawn is exposed to the greatest injuries which the floods in the breeding-rivers can inflict, whole beds of it being carried away by the 'spates' of winter, long before the egg has time to be hatched. And if fortunate enough not to be swept away by the flood, the eggs or ova become the prey of trout, worms, the larvæ of insects, and water-fowl, or are parched by the sun, if the water which covers them should happen, as is often enough the case, to be dried up, or run into a new channel. Even when spared from all these perils, the instant it is hatched the fish is exposed to new dangers; and more especially in the parr state is it destroyed in thousands, becoming the easy prey of every juvenile angler in the neighbourhood of our salmon-rivers. Instances, indeed, are known where these valuable fry have been caught in incredible numbers, for the purpose of feeding the swine of the neighbouring cottagers.

There are also many other causes which may have influenced the declining supply; and prominent among these an enormous destruction of grilses, and the annual massacre of spawning fish which used to take place. The capture of grilse at some of the fishing stations used to far outnumber that of salmon, and when it is considered that not one of these fish had been allowed to deposit its spawn before being killed, it will be at once seen how much this in time affected our supplies. Each grilse which the greed of profit induces people to kill before it is allowed to breed, will average from four to five pound-weight, and as the spawn is supposed to average 1000 eggs for each pound the salmon weighs, the number of future fish thus destroyed must have been immense. For instance, during a certain period of five years, the take of grilse on the Tweed in round numbers was 140,000; in previous years it averaged higher than that; but if we assume the spawn in each of the female fish at 3000, and take two-thirds of the number as females, or take 100,000 as such, the quantity of eggs destroyed would be nearly 300,000,000. If we suppose that even a hundredth part of this number of eggs had been allowed to grow up and reach the fishmonger's shop in the shape of full-grown salmon, we may see how completely the salmon proprietors had been exemplifying the proverb, and killing the goose that laid the golden eggs. Another evil with which salmon have to contend is the system of netting and 'leistering' which prevails, and which is still greatly resorted to in the breeding-time. The rivers are now so well watched as to have rendered the practice more infrequent than it was in the days of Sir Walter Scott and the Ettrick Shepherd, both of whom have described it with great power. Still, there must be a considerable loss from this source of illegal capture, as it is certain that salmon-poaching and the sale of foul fish are still carried on to a great extent, and the poachers, when they get into trouble, are greatly sympathised with, it being nothing uncommon for any fine which the magistrates may inflict upon them to be paid by a general subscription of the people of the district, where the peasantry still think they have a 'right' to kill the fish when they can get them.

There can be no doubt whatever that present legislation has improved the salmon-fisheries. Not only are more fish brought to market, but these are of a greater average weight, and are generally in finer condition than at one time, especially in the earlier part of the season. The economy of a salmon-river is only now beginning to be understood. It has dawned upon the minds of the lessees of the lower fishings, where most of the fish are got, that if a good breeding-stock is not allowed to ascend to the upper waters, it is certain that in a year or two the supply will begin to diminish.

With this view, on some salmon-rivers, artificial spawning has been resorted to, to keep up or increase the supplies. In connection with the salmon-fisheries of the Tay, there is a suite of

breeding-ponds at Stormontfield, which have been in operation for about twenty years; that at Howietoun on the Forth, near Stirling, is more important and successful. Various experiments of a testing nature as regards the natural history of the fish have been tried at Stormontfield by means of marks put upon the fish. Some important questions as to salmon-growth have been thus settled: it has been determined, for instance, that the parr *is* the young of the salmon in the first and second years of its age; that parr become smolts at the end of one and two years respectively from the time of birth; and that smolts *are* salmon; which was at one time hotly disputed. Many of the smolts marked at Stormontfield, on being let into the river on their way to the sea, have been captured as well-grown fish, and have denoted the growth of the salmon to be very rapid.

Very few of the 'salmon-lairds' 'fish' their own rivers, except in the way of sport. The fisheries are usually let—very often by public roup—to tenants, who do all the work of fishing, which is chiefly performed by net and cobble. Some economists say: 'What does it matter how you obtain your fish, so that you capture them.' But many good judges are of opinion that the art of catching should be studied, and with that view bag-nets, and even stake-nets, come in for a large amount of opprobrium. Proper close times have long been established, which admits of a portion of the fish attaining the head-waters, so as to afford a little sport to those gentlemen who may be said to afford them breeding-grounds, but more particularly it allows, in the tributary streams, places where the salmon can yield its eggs in comparative peace, and where, during the necessary period which they take to arrive at maturity, they may be nursed into life to the gentle music of the rippling streams.

There is a considerable commerce in salmon, and the largest supplies are obtained from the rivers of Scotland, from which, at one time, princely rentals were derived, and the rentals of which, even at present, are of great consequence. As with most other kinds of fish, London is the chief seat of consumption; the largest number of salmon sold in London are Scottish fish, the value of the salmon taken in Scottish streams being as much as £275,000. A salmon caught in the Spey or the Tay to-day can be in London to-morrow! Many of the salmon-fisheries are in the hands of 'tacksmen,' but others, as the river Spey, one of the best managed salmon-streams, is not let, but actually fished by its proprietor, the Duke of Richmond. One hundred thousand salmon and grilse per annum have often been obtained from this river, without in the least lowering the breeding-stock.

Considerable quantities of this fish are now being derived from some English streams, and some hundred boxes of Norwegian, Swedish, Dutch, and Rhine salmon are imported; a few also (refrigerated) from Canada. Of late an important fishing industry has sprung up in Oregon and British Columbia; enormous quantities of salmon are canned and exported. In the United States, artificial fish-breeding in 'hatcheries' is successfully prosecuted, not merely with reference to salmon and river fish, but lake fish (as 'white fish') and sea fish (as shad, cod, &c.).

Anglers' fishes have no great commercial value, the Loch Leven trout being perhaps an exception, and little effort has yet been made to cultivate our canals, lakes, and other waste waters. In France, where 'pisciculture' has made its mark, every little spot of water is turned to account—fish of all kinds being an absolute necessity at certain times to a Roman Catholic population.

VI. THE OYSTER AND OTHER SHELL-FISH FISHERIES.

Vast quantities of what are generally designated 'shell-fish' are consumed in London and other large cities. Shell-fish includes crabs, lobsters, cray-fish, muscles, periwinkles, and oysters. For the last edible there is such a constant and ever-increasing demand as almost to paralyse those industries which have been specially organised for its production and sale. The price of the oyster has increased within the last twenty years in a greater ratio than even that of the turbot, cod-fish, or salmon—one dozen of the mollusc costing in the retail shops about three shillings. The oysters brought to market are obtained both from natural scalps and artificial beds. The best example of a fine series of natural oyster-scalps is to be found at Newhaven, near Edinburgh; and the most famous artificial or cultivated layings are at Whitstable, on the coast of Kent, near Canterbury, where several well-managed oyster-farms may be seen.

The incessant demand for oysters during late years has had the effect of impoverishing many of the natural scalps. The Newhaven oyster-fishings, which were at one time held by the fishermen of that town at an almost nominal rent from the corporation of Edinburgh and from the Duke of Buccleuch, were at one period very productive, so much so, that oysters could be purchased in Edinburgh at less than one shilling per hundred; and if care had been taken to keep up an efficient quantity of breeding-stock, the supplies might still have been abundant; but tempted by high prices from English breeders, large quantities of 'brood' were sold to be fattened on the oyster-fields of Kent and Essex, in order that they might be sold as 'natives' in the shell-fish emporiums of London. The scalps at Newhaven belonging to the city of Edinburgh are now better regulated, whilst those belonging to the Duke of Buccleuch have been leased to a private dealer. The oysters dredged day by day in the season from Newhaven scalps are sold by auction, and very large prices are obtained for them, as much sometimes as ten shillings per hundred, the price varying according to appearance and quality. They are chiefly purchased by English buyers for the Manchester and London markets.

The largest supplies of oysters are required by those dealers who have their places of business in London, and a great portion of what they obtain is brought daily from Essex and Kent. The Whitstable Oyster Company is a well-organised industry of the co-operative kind, the proprietors of the farm being also the labourers who work it, and it is most systematically 'worked' both during the season and in close time. The company is possessed of a very large stock of oysters, which they purchase as 'brood' from whoever has brood to sell. These young oysters are laid down to grow and fatten, and are most carefully tended and watched till they are large enough to be sent

to market, it being a rule of the company to wait till they can obtain the highest possible price for their goods. Only a certain quantity is dredged each day—the sales being regulated by the state of the market. Great care is required in breeding oysters; the artificial layings at Whitstable are therefore under constant inspection, the different beds being turned over from time to time, in order to the removal of dead or diseased 'natives,' likewise for the capture and removal of some of the numerous enemies of the mollusc which are always to be found haunting the different beds.

The figures connected with oyster-farming as carried on at Whitstable are exceedingly interesting. The animal yields its *spat*, or young, in very large quantities—indeed, it would require to be very prolific, as the conditions which insure a healthy growth to the animal are often lacking. It is essential that young oysters should begin life on a rocky or shelly bottom, otherwise, they perish at once. Spat from natural beds is often carried by the combined influence of the winds and waves to a great distance from the parent scalp, where it may perish from falling on a muddy bottom, or under more genial circumstances may form the nucleus of a new bed. Some naturalists affirm that each oyster yields in its season more than one million of young, and that the animal begins to be reproductive at the age of four years. The breeding power of the oyster has perhaps been exaggerated, but to those who can be contented with approximate figures, we may state that a bushel measure is estimated to contain 25,000 infant oysters—that is, oysters that have not been long 'spatted;' in the second year of its age the oyster, then known technically as *brood*, has attained such a size that only about 6400 can be contained in the bushel; next year, as *ware*, the same measure holds 2400; and in its fourth year, when supposed to be full grown, the quantity contained in the bushel is about 1600: so that a bushel of spat, if it can be so grown and fattened as to reach the market at its maturity, will yield a very handsome profit to the oyster-farmer. The men at Whitstable earn excellent wages on their own oyster-farm, most of them on the average taking a hundred pounds a year out of the company; and many of them aid their income by acting as pilots, by going out to the coast-fisheries, and by gathering young oysters on the neighbouring free grounds, which they sell to their own company. About Whitstable and Faversham, the oyster-grounds occupy a space of nearly twenty-seven square miles; and it has been computed that £160,000 per annum has been paid as wages to the men connected with the various companies. The Whitstable oyster-layings are managed by a 'jury' of twelve men, who are elected by their fellows, and it is an article in the constitution of the company that no member can be elected into it —he must be born in it—so that sons succeed their fathers as workers and shareholders.

Ireland was at one time famous for its productive oyster-beds — natural scalps of great value. Now, Ireland is taking to 'oyster-culture,' as England and France have done. The Carlingford, Foyle, and Swilly oysters belong almost as much to the past as the fossil gryphæa —the first true oyster of geologists. That unquenchable greed for the golden egg, which seems to be the bane of all kinds of fisheries, led in Ireland, as in France, to the killing of the bird that laid it. At one time, fine oysters were plentiful and cheap in Dublin and at other places in Ireland, where the 'Poldoodies of Burran' were, like the 'natives' in London or the whiskered 'Pandores' of Prestonpans, a household word of the oyster-taverns. Brood-oysters were a few years ago extensively sold in Ireland by stupid men anxious for a little ready-money. As much as £8000 was paid for brood at Arklow by French and English oyster-growers. Attempts at oyster-culture are being successfully made in various parts of the Irish coast, and some portions of the sea-board of the Emerald Isle are well adapted for the formation of oyster-beds. In Clew and Newport bays, there are fifty or sixty miles of sea-bottom admirably adapted for oyster-farms.

In France, where, about forty years ago, there was a very productive series of natural oyster-scalps, experience has shewn the same results as in Great Britain and Ireland. So soon as easy means of transport began to be common, the oyster-beds were 'dredged to death,' so as to augment the sales of the day—the men taking no thought for the morrow. What they looked to was the ready-money produced by the immediate sales. From greed of gain, the natural beds of St Brieuc, Rochelle, Marennes, and other places, all became barren. In time the industry of oyster-cultivation was renewed by means of a cunning, artificial system of saving the spat. Great artificial beds at various places on the coast, and model farms, were constructed at the expense of the nation, so that those who cared to engage in the enterprise might be taught the best methods of oyster-farming. The most prominent of the French artificial oyster-beds are those of Arcachon, Marennes, and the Ile de Ré; there are many others, but these are the most celebrated. The artificial method of gathering the spat, now prevalent in France, was accidentally discovered by M. Bœuf of the Ile de Ré, who found a large quantity of small oysters adhering to some stones on the fore-shore—the seed having doubtless floated in to the island from some natural oyster-scalp. An immense quantity of oysters is required annually by the cafés of Paris, and the cities of the provinces never can obtain as many as they require. Artificial oyster-culture has been rather precarious during late years, in consequence of the irregular fall of the spat, but it is certain that large supplies continue to reach the markets, and that a great sum of money is yearly paid for this luxury of the table.

In America, the natural oyster-beds are of gigantic extent; some of them extending (as on the Virginia sea-board) to over a million of acres, and being free to all comers, give employment to thousands of industrious persons in dredging, canning, and carrying the oysters. 'Canned' oysters are known far and wide throughout the United States and Canada, hundreds of thousands of bushels being made up annually in small tins for conveyance by water or railway to the most distant places. Even with all its natural oyster-wealth, a note of alarm is being sounded by prudent people, who are of opinion that if dredging is continued for a few years longer on the same extensive scale as at present, the natural economy of the scalps

will be so interfered with as speedily to render them barren.

It is only at Billingsgate, the great wholesale fish-market of London, that a proper idea of the trade in oysters and other shell-fish can be obtained. A large portion of what Britain produces is there brought into a focus for distribution in London, and also for despatch to other places by train. At one time, the whole fish-trade of the great metropolis was centred at Billingsgate; that was at the period when fish of all kinds were chiefly sea-borne : now that railway trains (running special) bring up the daily 'harvest of the sea,' much of the produce is sent direct to the retail dealers, so that no accurate statistics of the fish-food of the period can be obtained.

Lobsters reach London from the most distant parts of the country—from Ireland, Shetland, Scotland, France, the Channel Islands, and Norway. This shell-fish is now a chief luxury of the table, being either served as sauce or salad. Countless numbers of them are sold daily in the London supper-houses, whilst a large supply is constantly required by private families. One dealer at Billingsgate turns over almost £50,000 a year, chiefly in the lobster-trade. The lobster is brought to market alive in vessels constructed for the purpose, and quantities of them are kept alive in stores or ponds, and also in boxes till required. The market is now seldom glutted with shell-fish, as a telegraphic message can diminish or augment the supplies according to the pulse of the market. It is needless to say that the mortality incidental to crustacean commerce is very great, and that fact tends, of course, to enhance the price of those animals that live to reach the market. Lobsters are caught in 'pots,' or traps, made of wicker-work. They are baited with any kind of garbage—the stronger-scented the better—and are then sunk in likely places of the water, and left to take their chance of a victim; whilst the industrious proprietor goes off trying to catch a few haddocks. On many parts of the Scottish coasts, perforated boxes, containing lobsters, may be seen floating, waiting for the weekly visit of the steam-boat to take up the cargo. Large supplies of this fine shell-fish are obtained from the Orkney Islands and from the coast of Sutherland. The value of the lobsters fished in Scotland in 1884 was £29,942.

The natural history of the lobster is remarkable, but need not be minutely detailed, as the following brief sketch of the crab will serve for both : The common edible crab is too well known to require description. The most remarkable feature in its economy, and which, indeed, is common to all crustaceans, is the process of sloughing, or moulting the shell at regular periods. As it is obvious that the hard shell, when once perfected, cannot change with the growth of the animal, it becomes necessary that it should be shed entirely. When the season of shedding arrives, the aquatic crabs generally seek the sandy shores of creeks and rivers, and having selected a place of rest, the change begins. The body seems to swell; the larger upper shell begins to separate from the breast or corselet; the muscles of the limbs soften and contract, which allows of their slipping from their cases; the parts about the head and antennæ undergo a similar change; and gradually the animal escapes from the crust, soft, helpless, and incapable of exertion or resistance. In twenty or thirty hours, however, a thin crust has again overspread its various parts and members, and in the course of a few days it is enabled to resume its wonted habits. During the moulting season, as well as during the period of spawning, crabs are uneatable; at other times, they are excellent. On the rocky coasts they frequent, they are either drawn at ebb-tide from the holes and crevices, by means of an iron hook, or they are fished for, in four or five fathoms water, by traps or cages baited with garbage. Immense numbers are annually consumed in all our seaports. It has been calculated that the commissariat of London alone requires every year about 3,000,000 of crabs, lobsters, and crayfish, besides countless quantities of whelks, periwinkles, and muscles. It may be mentioned that from one of the Orkney Islands hundreds of bags of periwinkles are, in the season, sent weekly to London by the steam-boats from Aberdeen.

To obtain muscles for bait is a necessity of fishery economy, and muscles are at present both scarce and dear, the natural beds having become exhausted from the increased quantity of bait now required for the cod-fish and haddock lines. Thirty or forty years ago, the number of hooks attached to each line was only about the half of what it is now, and, as a matter of course, they only required half the quantity of bait. A considerable portion of each fisherman's time is taken up in the search for muscles. From some fishing-ports the men have to take a two days' cruise in order to obtain a week's supply of this prime necessity of a successful fishing.

It is surprising that the fishermen of the British seas have not followed the plan of their French brethren, who, on one place at least of the coast of France (at Aiguillon, about four miles from La Rochelle), cultivate most successfully a large muscle-farm. The plan of cultivation adopted is one accidentally discovered three hundred years ago by a shipwrecked mariner. The spat or young of the muscle floats to the shore from some natural bed in the outer sea. It is then collected on huge pillars of wood, to which it adheres. As soon as the spat attains the dimensions of a small bean, it is gathered in little quantities, tied into a piece of netting or perforated canvas, and fixed upon a kind of artificial hedge, which is called a *bouchot*, where it is allowed to grow for a time. Several removals or transplantations take place, till, ultimately, the muscle finds itself almost on dry land, when it is found to have grown to marketable dimensions, and yields an excellent return for the pains bestowed on its cultivation. As much as one million francs have been derived from the muscle bouchots of Aiguillon in a year. There is no doubt that muscles might be extensively cultivated in this country. The bouchot is a very simple contrivance; a few pieces of wood driven into the muddy shore, and interlaced with the branches of trees, afford an excellent holding-on place for the young muscles; and as they can be transplanted from one place to another with the greatest ease, there is nothing to prevent the laying down of a muscle-farm on a hundred places of the coast of Great Britain and Ireland.

VII. CONCLUDING REMARKS—THE FUTURE OF THE FISHERIES.

As fish of all kinds are year by year becoming dearer, we are forced to the conclusion, that either the supply is decreasing, or the demand is increasing. It is stoutly maintained by some writers that 'there are as *good* fish in the sea as ever came out of it,' and also that 'there are as *many* fish in the sea as ever were drawn from it.' The literal truth of both sayings may be questioned: we know that it is quite possible to exhaust the natural supplies of fish, and there is good evidence that we diminished our stock of salmon by industriously capturing all that came to the nets, never thinking of leaving in the water a stock to breed from. The natural oyster-scalps fall off in productiveness when over-dredged, and in both Britain and France there is conclusive proof of over-dredging. As the reader will have learned from a perusal of the preceding pages, the herring-fishery is not thought to be so productive as the machinery of capture would warrant, and our shore haddock-fishery is almost exhausted; the aggregate size of some of the most accessible fishes has sensibly diminished; and there is a not unreasonable alarm that our fish-supplies may in time come to be seriously deficient.

In a blue-book containing 61,000 questions and answers, the result of a parliamentary inquiry into the condition of the British sea-fisheries, there is ample evidence of its being possible to exhaust, or at least break up, the most numerous shoals of sea-fish; but the commissioners who were appointed to make the inquiry of which this blue-book is the result, find in their Report that our 'total' fish-supplies 'have not diminished,' and tell us, that on the coasts of the United Kingdom the fish-supply admits of further augmentation, 'the limits of which are not indicated by any evidence we have been able to obtain.' But the commissioners unfortunately omitted to take into account the enormous augmentation of the machinery of capture. In former times, a line containing 800 hooks would, as a rule, capture 800 haddocks; but now, a line of 800 hook-power, does not (as a rule) capture an eighth part of the number! The public have been deceived by false reports of the inexhaustibility of our fish-supplies, and are at length beginning to find that the increased machinery which has been brought into play for the capture of fish during late years is telling with deadly effect on the shoals. Unfortunately, we have no complete statistics of the annual capture of white fish in the British seas; but, if we may judge from the carefully compiled figures of our most important sea-harvest (the herring-fishery), it seems quite possible, if not to exterminate, at anyrate seriously to affect the productive results of a given fishery. Nor could it well be otherwise; for little care is taken that a proper supply of breeding-fish is left in the shoals from which the supply can afterwards be obtained. It is, moreover, a fact, and a fact the importance of which seems to have been strangely overlooked, that a large number of fish cannot be obtained except when they congregate to spawn. To capture and cure herring full of milt and roe, is treated as a meritorious action; no other kinds obtain the 'full crown brand.' If it be criminal to kill a gravid salmon, it ought to be equally so to kill a gravid herring. In the case of Scotland, however, authentic statistics have been available since the division of the coasts into 26 distinct districts, and the publication of the valuable reports of the Fishery Board. From their last report, that for 1885, we learn that the total value of the fisheries of Scotland in 1884 was £3,351,849.

II. THE OIL-FISHERIES.

Gas, as a means of lighting both our houses and our cities, has to a great extent rendered us independent of the use of certain kinds of oil; but, nevertheless, the varieties of sea-animals and fish from which this valuable substance can be obtained are still in demand. In the preparation of jute, whale-oil is essential. In addition to the Greenland and sperm-whale fishery, we have various other sources of supply. From the liver of the valuable cod-fish, we derive an oil which occupies an important place in this country as a medicine; and the sunfish, or basking-shark, is also valuable, principally from the value of its liver. The seal also is now prized both for the sake of its skin, and because it yields a large quantity of oil; accordingly, many of the vessels now engaged in whale-fishing also make a voyage in search of seals. At one time, as many as 160 vessels of large tonnage left British ports for the whale-fishing; but owing to various causes, chiefly the discovery of other lubricants, and the scarcity of whales, there is not now a third of that number employed in the pursuit of the whale of the north seas; and it is chiefly American vessels that are engaged in the chase and capture of the spermaceti whales of the great south seas.

The cetaceous order of animals, of which the whale is the most remarkable and important member, is distinguished by various peculiarities, which render it a link, as it were, between the creatures of the land and the sea. While living in the ocean, and formed to make their way through its waters with ease and velocity, the cetacea differ from the true fish-tribes in being *mammalian*, or warm-blooded: having organs for respiring atmospheric air, like inhabitants of the land.

We will direct our attention to the Greenland whale, and to the spermaceti, as being typical members of the general family, which is very numerous, embracing as it does the Greenland or 'right whale,' the great rorqual, the cachalot or spermaceti whale, the narwhal, bottle-nose, ca'ing, and others.

The Greenland Whale. — Very exaggerated notions at one time prevailed as to the size of whales, some writers asserting that 160 feet was not an uncommon length. Dr Scoresby, however, declared that the common whale seldom or never exceeds seventy feet in length, and is more frequently under sixty. Out of 322 whales which he had personally aided in capturing, *not one* exceeded fifty-eight feet; and the largest ever taken, of which he knew the reported measurement to be authentic, was sixty-seven feet. The greatest girth is from thirty to forty feet, the thickest portion of the animal being immediately behind the head, which occupies a space equal to a third of the whole body. The whale is destitute of the back or dorsal fin, but possesses two pectoral fins,

which are situated about two feet behind the angles of the mouth, and are nearly five feet broad by nine feet in length. The tail, which is in the shape of a crescent, is horizontal, and about twenty-four feet broad. It is an instrument of immense power; and the whale has given strokes with it which have sent large boats high into the air in splinters. The colour of the body is mainly a velvety black; the under part of the head and abdomen, and the junction of the tail, being partly white, and partly of a freckled gray. The eyes of the whale are about a foot behind the angle of the mouth, and are not much larger than those of the ox. The iris is of a white colour, and the organs are guarded by lids and lashes, as in quadrupeds. The two blow-holes of the whale, situated on the summit of the head, and descending perpendicularly through it for a length of twelve inches into the windpipe, are the only other external features worthy of notice.

The mouth of the common whale is an organ of wonderful construction, and in a large specimen it may measure, when fully opened, sixteen feet long, twelve feet high, and ten feet wide. It contains no teeth; and enormous as the bulk of the creature is, its throat is so narrow that it would choke upon a morsel which an ox could easily swallow.

From this peculiarity, it may be anticipated that the food of the animal is composed of very minute substances. In fact, the whale feeds on a multitude of smaller inhabitants of the deep; and to permit this, its mouth is provided with a remarkable apparatus, composed of what is called *baleen*, the well-known *whalebone* of commerce. There are about 600 of these plates, and when dried, they weigh about a ton.

The use of these elastic plates, with their pendulous fringes, is to retain, as in a net, the multitude of small animals which are floated into the mouth of the whale whenever it is opened. Were it not for such a drainer, and the aid of the tongue, which is merely a great mass of fat tied down to the lower jaw, the emission of the water would be attended by the escape of all the objects which entered with it. As it is, the most minute matters are retained; and shrimps, sea-snails, small crabs, medusæ, &c. are entrapped by the great monster of the deep.

The skin of the whale consists of the scarf-skin or epidermis, which is moistened by an oily fluid, enabling it to resist the action of water; of the *rete mucosum*, a layer usually held to contain the colouring-matter of all animal surfaces; and of the true skin. This, for particular purposes, is open in texture, so as to contain the blubber, from which the oil is boiled out in great quantities. This mass, which surrounds the whole animal in a layer from one to two feet thick, and sometimes weighs more than thirty tons in all, serves the important end of keeping it warm by its weak conducting powers, and is also calculated to resist the enormous pressure to which its body must be subjected at the depths to which it often descends. Moreover, being inferior in specific gravity to water, this body of oil must be of great service in augmenting the buoyancy of the animal's frame. Below the skin are situated the muscles or flesh, which is red in colour, and tastes like coarse beef; and the character of this structure is much the same in the whale as in the ox or horse. With the exception of the tail, the arrangement of the various muscles of the whale does not differ very much from that of quadrupeds, and the same remark applies to the osseous structure. The fins are merely rudimental arms, containing nearly the same bones as in man, and the chest strongly resembles that of ordinary quadrupeds. The vertebral column of the rorqual whale contains sixty-three bones; those of the Greenland whale are not quite so numerous. The skull consists of the crown-bone, from which the facial bones and upper jaw project forward; while the lower jaw is composed of two long curved bones, that meet at the point or forepart of the mouth. These bones are hard and porous, and some of them contain large quantities of fine oil, but they have no proper medulla or marrow.

The organs of respiration in the whale are formed upon the same principle as those of land animals, but with modifications to suit the element in which the creature lives. As with terrestrial animals, the air gives a red colour to the blood, or, in other words, oxygenates it, and sustains the animal heat. Accordingly, the whale has frequently to come to the surface for air; but this operation is rendered less frequently necessary by the provision of a reservoir, consisting of a plexus of vessels filled with oxygenated blood, which can be drawn upon when required. The quantity of the blood, too, is great in proportion to the whole mass of the frame. The brain of the whale is held by Cuvier to be large in relation to the animal, but the arrangements of its nervous system are not understood. It is known that whales possess pretty acute vision, but there is a doubt whether or not they have any external ear. Their sense of smell seems to lie in the blow-holes, if anywhere. The strongest evidence, however, of their having the sense seems to be only the half-traditionary notion of sailors, that if certain strong-smelling substances are thrown overboard, whales will flee from the spot at once. The mammæ of the common whale are two in number, and attached to the abdomen; in the case of some other varieties, they are placed on the breast. The milk of the animal is said to be rich and creamy.

The cachalot or spermaceti whale differs from the Greenland species in having no baleen. It is much larger in size than the 'right whale,' being frequently found to extend to a length of seventy or eighty feet, and sometimes even attaining the extraordinary dimensions of ninety and a hundred feet, from the snout to the tail. Some species of the spermaceti whale possess two, others three fins; some have the spout in the neck, others in the snout; some have flat teeth, and others sharp teeth; and the colour of the back varies between black, blue, and gray. Generally speaking, the characteristics now to be noticed are common to all. The head is enormous, being fully more than a third of the whole body, and it ends like an abrupt and steep promontory in front. The size of head in the sperm-whale has a very extraordinary purpose to serve. To assist in floating the animal, a great cavity in the interior of the skull is filled with a fine oil, which becomes concrete on cooling, and forms spermaceti. Some of this oil is also found along the vertebral column; and in a bag in the intestines, or, as some writers say, in the fæces, ambergris is found. These are the principal objects of the sperm-whale fishery, the blubber procured from this variety of the

cetacea not being nearly so abundant as in the case of the mysticetus. At the same time, the blubber of the sperm-whale is valuable, and is converted into sperm-oil. The sailors know this whale at a great distance, by the act of blowing, which it performs with great regularity, at intervals of ten minutes or so. The sperm-whale is timid before man, yet it fights fiercely with those of its own race. Fights usually take place when male whales, or *bulls*, as they are called—one or two of which always attend a particular herd of females—meet with rivals. They lock jaws with one another, and exert a dreadful degree of power at one another's cost. When alarmed, or harpooned, they sometimes roll over and over on the surface of the water in an amazing manner. Still, they are not furious or dangerous towards the mariner, but are commonly killed with ease. The sailors call a herd a *school*, and the old bulls the *schoolmasters*. The females are said to be smaller than the males by a fourth. They are, like the Greenland whale, very fond of their young, and also of one another; so much so, that by cautious management, a whole herd may be destroyed, as they will scarcely quit a wounded companion. In this whale, the gullet is wide enough to admit a man, and the animal feeds on large fish. A cephalopodous mollusc, called *squid* by the sailors, is its chief food in deep seas. The mode of killing these leviathans of the deep is almost always the same, and whether they are Greenland or sperm whales, the harpoon is the instrument commonly used. Various new methods for killing the whale have been tried—such as a mortar to project shells into them, also a gun from which to fire the harpoon—but without much success.

THE SPERMACETI WHALE-FISHERY.

Some years ago, very little was known either about the natural history of the sperm-whale or of the great value of its products to mankind. It was only when one of these mighty animals happened to be stranded, that its oil was obtained; and the valuable spermaceti was popularly supposed to be derived from a different source. In those days, this substance was exceedingly scarce, and only to be purchased at druggists' shops as an ointment or medicine. In course of time, the value of the animal came to be discovered, its haunts were eagerly sought out, fleets of ships set off to explore, and its capture soon became a valuable source of gain, especially to the enterprising sailors of the American merchant-service.

The cachalot is certainly the largest inhabitant of the sea, the most valuable to man, and the most formidable to do battle with. The substances derived from it are sperm-oil, spermaceti, and occasionally ambergris. The South Sea whalers are vessels of about four hundred tons, and are smart, well-rigged ships, manned by expert seamen, who are paid by a share of the proceeds of the fishery. They provide for a long cruise: it lasts, on an average, from three to four years; and they differ in many respects from the Greenland ships, as they carry a furnace and boilers, called *trypots*, for the purpose of extracting the oil as soon as a fish is captured. The crew averages from about thirty to forty people, including the master, surgeon, mates, harpooners, &c. The best possible arrangements are made for the health of the crew, and the vessel is always kept as clean as the nature of the business carried on will admit. Five boats are usually attached to the whaler, provided with every requisite; chief among which is the whale-line, made of fine manilla hemp, two-thirds of an inch thick.

The great hunting-field for the sperm-whale is the Pacific Ocean. When the ship arrives on likely 'ground,' a sharp look-out is kept both for single whales and the *school*, or shoal, often to be seen led by one or two of the larger males or 'bulls.' The sperm-whales are in ordinary circumstances shy, and it requires much caution before those in pursuit can come so near a single fish as to strike it with a harpoon. Successive watchers are stationed upon each mast-head to keep a look-out—not in a 'crow's-nest,' like the Greenland whaler, but simply on the cross-trees, as the South Sea ships are not provided with a crow's-nest. When the magic cry 'There she spouts!' is sounded by the look-out, the crew start at once into a state of the greatest excitement. The boats are instantly lowered; the crew rapidly take their places, and away they pull, straining every nerve to come up with the huge leviathan before it dives. Arrived within reach of the animal, the command is given: 'Stand up, and give it to him.' The harpooner, dropping his oar, seizes his iron dart, and poising it high above his head, with unerring aim hurls it deep into the flesh of the gigantic cachalot. 'Stern all!' is now the cry, and the boat is backed out of reach of the stricken whale, while all the time the *line* is hissing over the gunwale with fierce velocity. The line runs out all its length; the boat, dragged by the whale, flies through the water, 'like a shark all fins.' As a whaleman says, 'whole Atlantics and Pacifics seem passed as they shoot on their way.' 'At length, tormented and wounded to death, the gigantic whale gets into that state known as the *flurry*, which may be described as the last dying flicker of the candle. After being "overwrapped in impenetrable and boiling spray, the whale once more rolls out into view," surging from side to side; spasmodically dilating and contracting his spout-hole, with sharp, cracking, agonised respirations. At last, gush after gush of clotted red gore, as if it had been the purple lees of red wine, shot into the frighted air; and falling back again, ran dripping down his motionless flanks into the sea.'

The next business is to tow the large carcase to the ship, where it is cut up, and the blubber boiled, for the purpose of extracting the oil. It is first firmly lashed to the side of the vessel, or suspended by appropriate gear from her rigging. The work of *flensing*, or cutting off the blubber or fat, must be expeditiously performed, for the hungry sharks, smelling the blood from afar, quickly surround the dead mass, anxious to obtain a meal. These devouring monsters congregate round the ship, and in a few hours the valuable mass would be reduced to a heap of bones, were it not speedily cut into strips, and carried on board. This process is performed by the crew, who are armed with sharp-cutting spades made for the purpose. A great mass is first cut away, and then hauled on board by means of a block and tackle. The head is got into the ship in one great mass, and then comes the command: 'Haul in the chains—let go the carcase.' 'The vast tackles,' says Melville, 'have now done their duty.

The peeled white body of the beheaded whale flashes like a marble sepulchre; though changed in hue, it has not perceptibly lost anything in bulk. It is still colossal. Slowly it floats more and more away, the water round it torn and splashed by the insatiate sharks, and the air above vexed with rapacious flights of screaming fowls, whose beaks are like so many insulting poniards in the whale.'

The spermaceti is now extracted from the head, and the preparation of the oil commences. Once kindled, the furnace gives out an intense heat, which is kept up by throwing in all the refuse matter. The apparatus for boiling is called the *try-works*, and the operation of boiling the blubber is termed *trying-out.* The harpooners, 'with huge pronged forks, pitch the hissing masses of blubber into the scalding pots, or stir up the fire beneath, till the smoky flames dart curling out of the doors to catch them by the feet. Anon the smoke rolls away in sullen heaps. To every pitch of the ship there is a pitch of the boiling oil, which seems all eagerness to leap from the copper.' After this process, the oil is conveyed to the coolers; and, finally, it is run into the barrels or tanks; and some day, the battered ship, after an absence of perhaps four years, runs to her port, and so finishes her adventures for the time.

RISE AND PROGRESS OF THE NORTHERN SEA WHALE-FISHERY.

It is natural to suppose that those nations dwelling on the shores of the arctic seas would be the earliest engaged in the whale-fishery; and accordingly we find that not only did the Norwegians and other Scandinavians precede all the other nations of Europe in this perilous but profitable line of enterprise, but they also were the first introducers of it among the southern nations. The shores of the Bay of Biscay, where the Normans formed early settlements, became famous, through them, for the whale-fishing there carried on. In the same region was it first made a regular commercial pursuit, and as whales then visited the bay in great numbers, the traffic was convenient and easy. The Biscayans maintained it with great vigour and success in the twelfth, thirteenth, and fourteenth centuries; they ultimately, however, relinquished the fishery from the want of fish, which ceased to come southward, no longer leaving the icy seas. The voyages of the Dutch and English to the Northern Ocean, in order to discover a passage through it to India, though they failed in their primary object, laid open the remote haunts of the whale. The British Muscovy Company obtained a royal charter, prohibiting all vessels but theirs from fishing in the seas round Spitzbergen, under pretence that it was discovered by Sir Hugh Willoughby. The fact, however, was, that Barentz, a merchant-seaman of Amsterdam, had discovered it in 1596; and neither Dutch, Spaniards, nor Frenchmen were at all disposed to admit the justice or propriety of the claim made by the English. An extraordinary scene followed in the northern seas. The Muscovy Company sent out six or seven strongly armed vessels, which took up a position near Spitzbergen, and commenced an attack on all foreign ships that refused either to quit the region at once, or pay the very moderate toll of one-half the proceeds of their fishing! The English succeeded so far as to annoy everybody else, and to prevent themselves from taking almost a single fish, so busy were they in looking after others. All the nations of Europe remonstrated loudly through their envoys against these proceedings; but the Dutch, ever fearless at sea, sent out a strong fleet, which effectually guarded their own fishing. At length, in 1618, a general engagement took place, in which the English were worsted. Hitherto, the two governments had allowed the fishing adventurers to fight out their own battles; but in consequence of the event mentioned, it was considered prudent to divide the Spitzbergen bays and seas into fishing-stations, where the companies might not trouble each other. After this period, the Dutch quickly gained a superiority over their rivals. While the English prosecuted the trade sluggishly, and with incompetent means, the Dutch turned their fisheries to great account, and in 1680 had about 260 ships and 14,000 sailors employed in them.

After the dissolution of the Muscovy Company, a Greenland Company, with an actual capital of £45,000, entered on the trade, and in nine years came to a ruinous close. In 1725, the South Sea Company took up the adventure; and in eight years, after a vast outlay, they also were compelled to submit to a dead loss of their capital, and throw up the attempt. The legislature now tried a new scheme, being sincerely desirous to encourage and establish the trade, as well as to make it a nursery for seamen. In 1732, a bounty of 30s. a ton was granted to every ship of 200 tons burden that engaged in the fishing. In 1749, it was thought necessary to raise the bounty to 40s. when, as Mr M'Culloch observes, as many ships seem to have been fitted out for catching the bounty as for catching fish. But a trade supported on any other principle than that of direct benefit received from it by the parties engaged therein, can never be enduring, and this truth soon appeared in the present case. In 1777, the bounty was reduced to 30s.; the consequence of which was, that during the next five years, the number of ships employed in the trade was reduced from 105 to 39! In 1781, the bounty was raised again to its old level, and an inducement was thus held out for the revival of the trade. But after all, what a million and a half of money, expended in successive donations under the name of bounty, was totally inefficient to do, the spirit of private enterprise, once fairly awakened, speedily accomplished. The British whale-fisheries throve rapidly between 1781 and 1795; and the legislature found themselves justified in reducing the bounty, at intervals, from 40s. to 20s. In any sketch of the whale-fishery, Peterhead deserves especial mention. The Peterhead Greenland fishing commenced in 1788, and for fourteen years afterwards, one vessel per annum regularly left the port in pursuit of the whale. In the first eight years, the produce was only six fish; but in 1798, greater enterprise began to be manifested, and some voyages produced as many as eleven whales. For many years a considerable number of ships have left this flourishing port.

The great difficulty in the whale-fishery is to get to the haunts of the animals in season, and the only proper method of doing so is to winter beyond the barrier of ice, which extends over a breadth of

250 miles. This method has now been successfully accomplished by harbouring in a position so that the edge of the land-ice may be reached by means of sledges and dogs in the month of May with the assistance of the natives.

A considerable amount of capital is required in 'whaling;' the vessels fitted out at Dundee or Peterhead, usually screw-steamers, are from four to six hundred tons, costing, when fully equipped, fifteen or sixteen thousand pounds. The vessels make one voyage to the seal-fishery, and another to the whale-fishery, in each year; they all stop for a time at Shetland, in order to take in their crews, the Shetlanders being hardy fellows, and good at the work. All the men of a vessel share more or less in the venture, having a percentage on the capture, as well as a fixed wage. Some of the chief functionaries, such as the harpooners, are paid high wages. A common sailor is paid, on an average, forty pounds sterling for the voyage.

THE SEAL-FISHERY.

The seal is not a member of the Whale family, but belongs to a distinct order of marine mammalia, called the *Phocidæ*, which are more fish-like than the cetaceans. Seals are carnivorous, and live mostly on fish; existing chiefly in the water, they usually bring forth their young on the ice, on which they delight at times to squat. The natural history of the seal is still very obscure: there are several genera and species, but it is the genus *Phoca* which forms the object of pursuit in the arctic seas. The common seal is from three to five feet long, but some are much larger, extending from eight to ten feet in length, and being of corresponding girth. There have been curious speculations as to some points of the natural history of the seal. It was stated by Provost Yeaman of Dundee, at the meeting of the British Association which was held in Dundee, that the young seals killed in the spring were mostly, if not altogether males! Some experienced men long engaged in the seal-ing-trade say they never saw a female, and it is inferred from this circumstance that the animal must breed twice a year. They produce one or two at a birth.

The first capture of seals, as a matter of commerce, of which we have an authentic account, was in 1803, when Captain Geary of the *Robert* brought home 180 along with his seven whales. Large numbers are caught; ships have been known to bring home as many as 22,000; and from 3000 to 5000 is common.

The vessels employed in the seal-fishery usually leave this country about the end of February, or beginning of March. They are generally delayed at Lerwick (Shetland Isles) for a week or so, where they engage the greater number of their crew. Seals are found in great numbers in the Greenland seas; but the principal place for hunting them is at Spitzbergen, where numerous herds are to be found both on the ice and on the land. They are easily wounded by means of a spear; but they are difficult to kill, and are sometimes deprived of their skin before life becomes extinct. To say the truth, the scene is a terrible one —it is sheer butchery, the seals being put to death with clubs or guns, or whatever comes readiest to hand. The usual day's work for a ship's crew is to kill five hundred old seals, and two thousand young ones. Useless labour is saved by skinning the seal where it falls. With the skin, as much of the blubber is brought away as possible. A young seal about a fortnight or three weeks old will yield thirty pounds of blubber; of course, the old ones yield more. The labour of dragging the skins to the ship, which may be a good way off, is considerable; and after that, the skins have to be scraped, the fat being placed in barrels, and the skins stowed away in the hold. These, as the reader is aware, are used for a great variety of purposes; and the oil of the seal is preferred in many respects to that of the whale.

The beautiful seal-skin jackets of commerce are the product rather of *otaries* than of seals proper. The supply was formerly obtained from the southern seas; but is now mainly procured from islands off the coast of Alaska. It may be remarked, *en passant*, that a large number of the jackets and cloaks which are sold as 'real seal-skin' are not made out of seal-skin at all, but are only clever imitations, made out of beaver, rabbit, or other skins.

PRESERVATION OF HEALTH.

A HUMAN being, supposing him to be soundly constituted at first, will continue in health till he reaches old age, provided that certain conditions are observed, and no injurious accident shall befall. This is a proposition so well supported by extensive observation of facts, that it may be regarded as an established maxim. It becomes, therefore, important to ascertain what are the conditions essential to health, that, by their observance, we may preserve for ourselves what is justly esteemed as the greatest of earthly blessings, and dwell for our naturally appointed time upon the earth. A general acquaintance with these conditions may be easily attained by all, and to render them obedience is much more within the power of individuals than is commonly supposed.

The leading conditions essential to health are—1. A constant supply of pure air; 2. A sufficiency of nourishing food, rightly taken; 3. Cleanliness; 4. A sufficiency of exercise to the various organs of the system; 5. A proper temperature; 6. A sufficiency of cheerful and innocent enjoyments; and, 7. Exemption from harassing cares. These conditions we shall now treat in succession, taking as our guides the most recent and eminent of physiological authorities.

AIR.

The common air is a fluid composed mainly of two gases, in certain proportions—namely, 20 parts of oxygen and 80 of nitrogen in 100, with a very minute addition of carbonic acid gas. (See CHEMISTRY.) Such is air in its pure and normal state, and such is the state in which we require it for respiration. When it is loaded with any admixture of a different kind, or its natural proportions are in anyway deranged, it cannot be breathed without producing injurious results. We also require what is apt to appear a large quantity of this element of healthy existence. The lungs of a healthy full-grown man will inhale the bulk of twenty cubic inches at every inspiration, and he will use no less than fifty-seven hogsheads in twenty-four hours. And not only is this large quantity necessary, but the air that surrounds us must be in free circulation, in order that what we expire may be speedily carried away, and allowed to commingle with the atmosphere, which is subject to never-ceasing causes tending to its restoration and renewal.

Now, there are various circumstances which tend to surround us at times with vitiated air, and which must accordingly be guarded against. That first calling for attention is the miasma or noxious quality imparted to the atmosphere in certain districts by stagnant water and decaying vegetable matter. It is now generally acknowledged that this noxious quality is, in reality, a subtile poison, which acts on the human system through the medium of the lungs, producing fevers and other epidemics. A noted instance of its thus acting on a great scale is presented in the Campagna di Roma, where a large surface is retained in a marshy state. The exhalations arising from that territory at certain seasons of the year, oblige the inhabitants of the adjacent districts to desert their homes, and escape their pernicious influence. All marshes, and low damp grounds of every kind, produce more or less miasma; and it is consequently dangerous to live upon or near them. Slightly elevated ground, with a free exposure to light and air, should, accordingly, in all cases be chosen for the sites of both single houses and towns. Tanks and collections of water of every kind are dangerous beneath or near a house, because, unless their contents be constantly in a state of change, which is rarely the case, their tendency is to send up exhalations of a noxious kind. Some years ago, Viscount Milton—a youth of great promise, and who had recently become a husband and father—died of a fever which was traced to the opening of an old reservoir of water underneath the country-house in which he dwelt. A similar, but more extensively fatal tragedy took place at a farmhouse in the south of Scotland. Not only did the farmer, his wife, and a female servant sink under a malignant fever, but a son and daughter, and several other servants, narrowly escaped with their lives, and only by removing from the house. It was observed in this case that removal produced instantaneous improvement of health, but a return to the devoted dwelling at once renewed the ailment. On proper investigation, it was found that immediately behind the house was a kind of millpond, into which every kind of refuse was thrown, or allowed to discharge itself; and that this collection of putrid matter had not been once cleared out for a long series of years, no one dreaming of any harm from it. The momentous consequences from a cause so trifling, and the consideration that they might have been warded off by only a little knowledge of natural causes, furnish melancholy matter for reflection. Many analogous cases, which might be referred to, demonstrate that we are yet but in the infancy of an understanding of the subject of aërial poisons.

Putrid matter of all kinds is another conspicuous source of noxious effluvia. The filth collected in ill-regulated towns—ill-managed drains—collections of decaying animal substances placed too near or within private dwellings—are notable for their effects in vitiating the atmosphere and generating disease in those exposed to them. In this case also it is a poison, diffused abroad through the air, which acts so injuriously on the human frame. This was probably the main cause of the plagues which devastated European cities during the middle ages. In those days there were no adequate provisions for public cleaning, and the consequence was, that masses of filth were suffered to accumulate. The

noxious air diffused by these means through the narrow streets and confined dwellings would tend to the most fatal effects. In old drains there is generated a gas—sulphuretted hydrogen—which is calculated to produce dreadful consequences in those exposed to its inhalation. It has lately been discovered that it is the presence of this gas, arising from the shores, river deltas, and mangrove jungle of tropical Africa, which causes the peculiar unhealthiness of that region. It is ascertained that small animals, such as birds, die when the air they breathe contains one-fifteen-hundredth part of sulphuretted hydrogen, and that an infusion six times greater will kill a horse. It follows that we can scarcely attach too much importance to measures for cleaning and improving the sewerage of cities. There are as yet no large towns in Britain kept in a state so clean as is desirable for the welfare of their inhabitants; nor will they be so till the measures now in agitation for improved modes of construction, for adequate supplies of pure water, and for thorough scavengering and sewerage, be adopted.

The human subject tends to vitiate the atmosphere for itself, by the effect which it produces on the air which is breathed. Our breath, when we draw it in, consists of the ingredients formerly mentioned, but it is in a very different state when we part with it. On passing into our lungs, the oxygen, forming the lesser ingredient, enters into combination with the carbon of the venous blood —or blood which has already performed its round through the body: in this process about two-fifths of the oxygen is abstracted and sent into the blood, only the remaining three-fifths being expired along with the nitrogen nearly as it was before. In place of the oxygen consumed, there is expired an equal volume of carbonic acid gas, such gas being a result of the process of combination just alluded to. Now, carbonic acid gas in a larger proportion than that in which it is found in the atmosphere, is noxious. The volume of it expired by the lungs, if free to mingle with the air at large, will do no harm; but if breathed out into a close room, it will render the air unfit for being again breathed. Suppose an individual to be shut up in an air-tight box; each breath he emits throws a certain quantity of carbonic acid gas into the air filling the box; the air is thus vitiated, and every successive inspiration is composed of worse and worse materials, till at length the oxygen is so much exhausted that it is insufficient for the support of life. He would then be sensible of a great difficulty in breathing, and in a little time longer he would die.

Most rooms in which human beings live are not strictly close. The chimney and the chinks of the door and windows generally allow of a communication to a certain extent with the outer air, so that it rarely happens that great immediate inconvenience is experienced in ordinary apartments from want of fresh air. But it is at the same time quite certain that in all ordinary apartments where human beings are assembled, the air unavoidably becomes *considerably vitiated;* for in such a situation there cannot be a sufficiently ready or copious supply of oxygen to make up for that which has been consumed—the carbonic acid gas will be constantly accumulating, and there is also putrefying organic matter in the vapour of the breath. This is particularly the case in bed-chambers, and in theatres, assembly-rooms, churches, and schools. An extreme case was that of the celebrated Black Hole of Calcutta, where 146 persons were confined for a night in a room eighteen feet square with two small windows. Here the oxygen, scarcely sufficient for the healthy supply of one person, was called upon to support a large number. The unfortunate prisoners found themselves in a state of unheard-of suffering; and in the morning all were dead but twenty-three, some of whom afterwards sunk under putrid fever, brought on by breathing so long a tainted atmosphere.

Although the vitiation of the air in ordinary apartments and places of public assembly does not generally excite much attention, it nevertheless exercises a certain unfavourable influence on health in all the degrees in which it exists. Perhaps it is in bedrooms that most harm is done. These are generally smaller than other rooms, and they are usually kept close during the whole night. The result of sleeping in such a room is very injurious. A common fire, from the draught which it produces, is very serviceable in ventilating rooms, but it is at best a defective means of doing so. The draught which it creates generally sweeps along near the floor between the door and the fire, leaving all above the level of the chimney-piece unpurified. Yet scarcely any other arrangement is anywhere made for the purpose of changing the air in ordinary apartments. To open the window is a plan occasionally resorted to, but it is not always agreeable in our climate, and sometimes it produces bad consequences of a different kind.

A plan, to a considerable extent serviceable, though not perfect, for producing a draught from a room possessing a fire-place, was suggested by the philanthropic Dr Arnott. It is only necessary to make an aperture into the flue, near the ceiling of the room, and insert therein a tin tube, with a valve at the exterior, capable of opening inwards, but closing when at rest, or when a draught is sent the contrary way. The draught produced by the fire in the flue causes a constant flow of air out of the *upper part* of the room (where most vitiated); and the valve is a more or less effectual protection against back-smoke. This plan can be applied to any existing house at a mere trifle of expense. (For various modes of ventilation, see No. 31.)

FOOD.

The second requisite for the preservation of health is—a sufficiency of nutritious food.

Organic bodies are constituted—as explained under PHYSIOLOGY—upon the principle of *a continual waste of substance supplied by continual nutrition.* The nutritive system of animals, with the exception of the very lowest animal organisms (see ZOOLOGY, vol. i. 129), comprehends an *alimentary tube* or *cavity*, into which food is received, and from which, after undergoing certain changes, it is diffused by means of smaller vessels throughout the whole structure. In the form of this tube, and in the other apparatus connected with the taking of food, there are in different animals varieties of structure, all of which are respectively in conformity with peculiarities in the quality and amount of food which the particular animals are designed to take.

Man designed to live on a Mixed Diet.

The followers of Pythagoras argued, from the cruelty of putting animals to death, that it was proper to live on vegetables alone; and eccentric persons of modern times have acted upon this rule. But the ordinances of Nature speak a different language; and if we have any faith in these, we cannot for a moment doubt that a mixture of animal food is necessary for our well-being. On the other hand, we cannot dispense with vegetable food without injurious consequences. In that case, we place in a medium alimentary canal a kind of food which is calculated for a short one, thus violating an arrangement of the most important nature. A balance between the two kinds of food is what we should observe, if we would desire to live a natural and healthy life.

Rules connected with Eating.

In order fully to understand how to eat, what to eat, and how to conduct ourselves after eating, it is necessary that we should be acquainted in some measure with the *process of nutrition*—that curious series of operations by which food is received and assimilated by our system, in order to make good the deficiency produced by waste.

Even in the introductory stage there are certain rules to be observed. Strange as it may appear, to know *how to eat* is physiologically a matter of very considerable importance. Many persons, thinking it all a matter of indifference, or perhaps unduly anxious to despatch their meals, eat very fast. If we are to believe the accounts of travellers, the whole of the mercantile classes in the United States of America eat hurriedly, seldom taking more than ten minutes to breakfast, and a quarter of an hour to dinner. They tumble their meat precipitately into their mouths, and swallow it almost without mastication. This is contrary to an express law of nature, as may be very easily demonstrated.

Food, on being received into the mouth, has two processes to undergo, both very necessary to digestion: it has to be masticated, or chewed down, and also to receive an admixture of saliva. The saliva is a fluid arising from certain glands in and near the mouth, and approaching in character to the gastric juice afterwards to be described. Unless food be well broken down or masticated, and also well mixed up with the salivary fluid, it will be difficult of digestion. The stomach is then called upon to perform, besides its own proper function, that which properly belongs to the teeth and saliva, and it is thus overburdened, often to a very serious extent. The pains of indigestion are the immediate consequence, and more remote injuries are likely to follow.

The importance of the saliva has been shewn in a striking manner on several occasions when food was received into the stomach otherwise than through the mouth. A gentleman, who, in consequence of a stricture in the gullet, had his food introduced by an aperture into that tube, used to suffer severely from indigestion. It is recorded of a criminal, who, having cut his throat in prison without fatal consequences, required to get his food introduced by means of a tube inserted by the mouth, that every time he was fed there was an effusion of saliva to the amount of from six to eight ounces. We cannot suppose that a fluid of a peculiar character would have been prepared in such quantity, when water would serve as well merely to moisten the food, if it had not been designed to act an important part in the business of nutrition.

With regard to mastication, the evidence of its importance is still more decided. Some years ago, a young Canadian, named Alexis St Martin, had a hole made by a shot into his stomach, which healed without becoming closed. It was therefore possible to observe the whole operations of the stomach with the eye. His medical attendant, Dr Beaumont, by these means ascertained that when a piece of solid food was introduced, the gastric juice acted merely on its outside. It was only when the food was comminuted, or made *small*, that this fluid could fully perform its function. When the stomach finds itself totally unable to digest a solid piece of food, it either rejects it by vomiting, or passes it on into the gut, where it produces an irritating effect, and is apt to occasion an attack of colic or flatulency. It must therefore be concluded, that *a deliberate mastication of our food is conducive to health, and that fast eating is injurious, and sometimes even dangerous.*

The food, having been properly masticated, is by the action of the tongue thrown into the gullet. It then descends into the stomach, not so much by its own gravity, as by its being urged along by the contractions and motions of the gullet itself. The stomach may be considered as an expansion of the gullet, and the chief part of the alimentary canal. It is, in fact, a membranous pouch or bag, very similar in shape to a bagpipe, having two openings, the one by which the food is admitted, the other that by which it is passed onward. It is into the greater curvature of the bag that the gullet enters; at the lesser, it opens into that adjoining portion of the canal into which the half-digested mass is next propelled.

When food has been introduced, the two orifices close, and that which we may term the second stage in the process of digestion commences. The mass, already saturated with saliva, and so broken down as to expose all its particles to the action of the gastric juice, is now submitted to the action of that fluid, which, during digestion, is freely secreted by the vessels of the stomach. The most remarkable quality of this juice is its solvent power, which is prodigious.

The food exposed to this dissolving agency is converted into a soft, gray, pulpy mass, called *chyme*, which, by the muscular contraction of the stomach, is urged on into the adjoining part of the alimentary canal, called the *duodenum*. This is generally completed in the space of from half an hour to two or three hours; the period varying according to the nature and volume of the food taken, and the degree of mastication and insalivation it has undergone.

In the duodenum, the chyme becomes intimately mixed and incorporated with the bile and pancreatic juices; also with a fluid secreted by the mucous follicles of the intestine itself. The bile is a greenish, bitter, and somewhat viscid fluid, secreted by the liver, which occupies a considerable space on the right side of the body immediately under the ribs. From this organ the bile, after a portion of it has passed up into the adjacent gall-bladder, which serves as a reservoir, descends through a small duct, about the size of

a goose-quill, into the duodenum. The chyme, when mixed with these fluids, undergoes a change in its appearance: it assumes a yellow colour and bitter taste, owing to the predominance of the bile in the mass; but its character varies according to the nature of the food that has been taken. Fatty matters, tendons, cartilages, white of eggs, &c. are not so readily converted into chyme as fibrous or fleshy, cheesy, and gelatinous substances. The chyme, having undergone the changes adverted to, is urged by the peristaltic motion of the intestines onwards through the alimentary canal. This curious motion of the intestines is caused by the contraction of the muscular coat which enters into their structure, and one of the principal uses ascribed to the bile is that of stimulating them to this motion. If the peristaltic motion be diminished, owing to a deficiency of bile, then the progress of digestion is retarded, and the intestines become constipated. In such cases, calomel, the blue pill, and other medicines, are administered, for the purpose of stimulating the liver to secrete the biliary fluid, that it may quicken, by its stimulating properties, the peristaltic action.

The preceding, however, is not the only use of the bile; it also assists in separating the nutritious from the non-nutritious portion of the alimentary mass, for the chyme now presents a mixture of a fluid termed *chyle*, which is in reality the nutritious portion eliminated from the food. The chyme thus mixed with chyle arrives in the small intestines, on the walls of which a series of exquisitely delicate vessels ramify in every direction. These vessels absorb or take up the chyle, leaving the rest of the mass to be ejected from the body. The chyle, thus taken up, is carried into little bodies or glands, where it is still further elaborated, acquiring additional nutritious properties; after which corresponding vessels, emerging from these glands, carry along the fluid to a comparatively large vessel, called the thoracic duct, which ascends in the abdomen along the side of the backbone, and pours it into that side of the heart to which the blood that has already circulated through the body returns. Here the chyle is intimately mixed with the blood, which fluid is now propelled into the lungs, where it undergoes, from being exposed to the action of the air we breathe, the changes necessary to render it again fit for circulation. It is in the lungs, therefore, that the process of digestion is completed: the blood has now acquired those nutritive properties from which it secretes the new particles of matter adapted to supply the waste of the different textures of the body.

When food is received into the stomach, the secretion of the gastric juice immediately commences; and when a full meal has been taken, this secretion generally lasts for about an hour. It is a law of vital action, that when any living organ is called into play, there is immediately an increased flow of blood and nervous energy towards it. The stomach, while secreting the gastric juice, displays this phenomenon, and the consequence is that the blood and nervous energy are called away from other organs. This is the cause of that chilliness at the extremities which we often feel after eating heartily. So great is the demand which the stomach thus makes upon the rest of the system, that during and for some time after a meal we are not in a condition to take strong exercise of any kind. Both body and mind are inactive and languid. They are so simply because that which supports muscular and mental activity is concentrated for the time upon the organs of digestion. This is an arrangement of nature which a regard to health requires that we should not interfere with. *We should indulge in the muscular and mental repose which is demanded; and this should last for not much less than an hour after every regular meal.* In that time the secretion of gastric juice is nearly finished, and we are again fit for active exertion. The consequence of not observing this rule is often very hurtful. Strong exercise, or mental application, during or immediately after a meal, diverts the flow of nervous energy and of blood to the stomach, and the process of digestion is necessarily retarded or stopped. Confusion and obstruction are thus introduced into the system, and a tendency to the terrible calamity of dyspepsy is perhaps established.

For the same reason that repose is required after a meal, it is necessary in some measure for a little while before. At the moment when we have concluded a severe muscular task—such, for example, as a long walk—the flow of nervous energy and of circulation is strongly directed to the muscular system. It requires some time to allow this flow to stop and subside; and till this takes place, it is not proper to bring the stomach into exercise, as the demand which it makes when filled would not in that case be answered. In like manner also, if we be engaged in close mental application, the nervous energy and circulation being in that case directed to the brain, it is not right all at once to call another and distant organ into play; some time is required to allow of the energy and circulation being prepared to take the new direction. It may therefore be laid down as a maxim, that *a short period of repose, or at least of very light occupation, should be allowed before every meal.*

It is remarkable that these rules, although the natural reasons for them were not perhaps well known, have long been followed with regard to animals upon which man sets a value, while as yet their application to the human constitution is thought of only by a few. Those intrusted with horses and dogs will not allow them to feed immediately after exercise; nor will they allow them to be subjected to exercise for some time after feeding. Experience has also instructed veteran soldiers not to dine the instant that a long march has been concluded, but to wait coolly till ample time has been allowed for all the proper preparations.

Although strong mental and muscular exercise should be avoided before, during, and immediately after a meal, there can be no objection to the light and lively chat which is generally indulged in where several are met to eat together. On the contrary, it is believed that jocund conversation is useful towards the process of nutrition.

Kinds of Food.

It has been shewn, by a reference to the structure of the human intestinal canal, that our food is designed to be a mixture of animal and vegetable substances. There is, it is to be remarked, a power of adaptation in nature, by which individuals may be enabled for a considerable time to

live healthily on one or the other kind exclusively, or nearly so. The above is, nevertheless, the general rule, to which it is safest to adhere. It has been found, for instance, that field-labourers, including ploughmen, will live healthily for many years on a diet chiefly farinaceous—that is, composed of the farina of grain. But it is to be feared that the food in this case, though apparently sufficient for health, is only so apparently; and that the constitution, being all the time not supported as it ought to be, breaks down prematurely in a great proportion of instances. It has been said, again, that the Irish labouring-classes are a remarkably robust race, although their food consists almost exclusively of potatoes. The fact is overlooked, that the Irish eat a quantity of potatoes so enormous as could not fail to make up in some measure for the want of animal diet. It was found by the Poor-law Commissioners, that the greater number of the peasantry of Ireland, women as well as men, take at their two daily meals in general about nine pound-weight of this aliment! Such a case is rather to be ranked amongst instances of extraordinary adaptations to a particular variety of food, than as a proof that an unmixed potato-diet is healthy.

Climate has a remarkable effect in modifying the rule as to the mixture and amount of animal and vegetable food. The former has most of a stimulating quality, and this quality is greater in beef, and flesh in general, than in fowl or fish. Now, the inhabitants of torrid countries are, in their ordinary condition, least in need of stimulus; hence they find a simple diet of rice and sago sufficient for them. Those, on the contrary, who dwell in cold countries need much stimulus; hence they can devour vast quantities of flesh and blubber, with scarcely any mixture of vegetable food.

Inquiries with respect to the comparative digestibility of different kinds of food are perhaps chiefly of consequence to those in whom health has already been lost. To the sound and healthy, it is comparatively of little consequence what kind of food is taken, provided that some variation is observed, and no excess committed as to quantity. Within the range of fish, flesh, and fowl, there is ample scope for a safe choice. There is scarcely any of the familiar aliments of these kinds but, if plainly dressed, will digest in from two to four hours, and prove perfectly healthy. One rule alone has been pretty well ascertained with respect to animal foods, that they are the more digestible the more minute and tender the fibre may be. They contain more nutriment in a given bulk than vegetable matters, and hence their less need for length of intestine to digest them. Yet it is worthy of notice, that between the chyle produced from animal and that from vegetable food no essential distinction can be observed.

Tendon, suet, and oily matters in general, are considerably less digestible than the ordinary fibre; and these are aliments which should be taken sparingly. Pickling, from its effect in hardening the fibre, diminishes the digestibility of meat. Dressed shell-fish, cheese, and some other animal foods are avoided by many as not sufficiently digestible.

Farinaceous foods of all kinds—wheat, oaten, and barley bread, oaten porridge, sago, arrow-root, tapioca, and potatoes—are highly suitable to the human constitution. They generally require under two hours for digestion, or about half the time of a full mixed meal. The cottage children of Scotland, reared exclusively upon oaten porridge and bread, with potatoes and milk, may be cited as a remarkable example of a class of human beings possessing in an uncommon degree the blessing of health. One important consideration here occurs: there is need for a certain bulk in our ordinary food. Receiving nutriment in a condensed form, and in a small space, will not serve the purpose. This is because the organs of digestion are calculated for receiving our food nearly in the condition in which nature presents it—namely, in a considerable bulk with regard to the proportion of its nutritious properties. The same law applies with respect to the lower animals. When a horse is fed upon corn alone, it does not thrive. The present writer is much inclined to doubt the propriety of grinding off the coarse exterior of wheaten grain. It does not seem by any means likely that nature calculated the human alimentary cavity for the use of the white interior of the grain, exclusive of all the rest, which consists of very different but not less necessary chemical constituents. Wheat forms so large a part of our daily food, that if this be the case, we unquestionably make a departure of a very important kind from the laws of health. Experience is favourable to this view, for the effect of coarse brown bread in relaxing, seems only comparable to that of white bread in constipating the bowels.

Quantity of Food—Number and Times of Meals.

With respect to the amount of food necessary for health, it is difficult to lay down any rule, as different quantities are safe with different individuals, according to their sex, age, activity of life, and some other conditions. There is a general and probably well-founded opinion, that most persons who have the means eat too much, and thereby injure their health. This may be true, and yet it may not be easy to assign to such persons a limit beyond which they ought not to go.

The best authorities are obliged to refer the matter to our own sensations. Dr Beaumont, for example, says that we should not eat till the mind has a sense of *satiety*, for appetite may exceed the power of digestion, and generally does so, particularly in invalids; but to a point previous to that, which 'may be known by the pleasurable sensations of *perfect satisfaction, ease, and quiescence of body and mind.*'

The number and times of meals are other questions as yet undetermined. As the digestion of a meal rarely requires more than four hours, and the waking part of a day is about sixteen, it seems unavoidable that at least three meals be taken, though it may be proper that one, if not two of these, be comparatively of a light nature. Breakfast, dinner, and tea as a light meal, may be considered as a safe, if not a very accurate prescription for the daily food of a healthy person. Certainly four good meals a day is too much. No experiments, as far as we are aware, have been made with regard to the total amount of solids which a healthy person in active life may safely take in a day. It has been found, however, that confined criminals and paupers are healthiest when the daily solids are not much either above or below twenty-five ounces. Of course, in active life

there must be need for a larger allowance, but only to a small extent. We may thus arrive at a tolerably clear conviction of the reality of that excess which is said to be generally indulged in; for certainly most grown people who have the means, not excepting many who pursue very sedentary lives, eat *much more* than twenty-five ounces.

The interval between rising and breakfast ought not to be great, and no severe exercise or task-work of any kind should be undergone during this interval. There is a general prepossession to the contrary, arising probably from the feeling of freedom and lightness which most people feel at that period of the day, and which seems to them as indicating a preparedness for exertion. But this feeling, perhaps, only arises from a sense of relief from that oppression of food under which much of the rest of the day is spent. It is quite inconsistent with all we know of the physiology of aliment to suppose that the body is capable of much exertion when the stomach has been for several hours quite empty. We have known many persons take long walks before breakfast, under an impression that they were doing something extremely favourable to health. Others we have known go through three hours of mental task-work at the same period, believing that they were gaining so much time. But the only observable result was, to subtract from the powers of exertion in the middle and latter part of the day. In so far as the practice was contrary to nature, it would likewise, of course, produce permanent injury. Only a short saunter in the open air, or a very brief application to business or task-work, can be safely indulged in before breakfast.

Variety of Food.

A judicious variation of food is not only useful, but important. There are, it is true, some aliments, such as bread, which cannot be varied, and which no one ever wishes to be so. But apart from one or two articles, a certain variation or rotation is much to be desired, and will prove favourable to health. There is a common prepossession respecting *one dish*, which is more spoken of than acted upon. In reality, there is no virtue in this practice, excepting that, if rigidly adhered to, it makes excess nearly impossible, no one being able to eat to satiety of one kind of food. There would be a benefit from both a daily variation of food and eating of more than one dish at a meal, *if moderation were in both cases to be strictly observed;* for the relish to be thus obtained is useful, as promotive of the flow of nervous energy to the stomach, exactly in the same manner as cheerfulness is useful. The policy which would make food in any way unpleasant to the taste is a most mistaken one; for to eat with languor, or against inclination, or with any degree of disgust, is to lose much of the benefit of eating. On the other hand, to cook dishes highly, and provoke appetite by artificial means, are equally reprehensible. Propriety lies in the mean between the two extremes.

Beverages.

The body containing a vast amount of fluids which are undergoing a perpetual waste, there is a necessity for an occasional supply of liquor of some kind, as well as of solid aliment. It remains to be considered what is required in the character or nature of this liquor, to make it serve as a beverage consistently with the preservation of health.

It is scarcely necessary to remark how men in all ages, and almost all climes, have indulged in liquors containing a large infusion of alcohol, or how wide-spread in our own society is the custom of drinking considerable quantities of wine, spirits, and beer, both at meals and on other occasions. Against habits so inveterate, it is apt to appear like fanaticism to make any decided objection; yet the investigator of the laws which regulate health is bound to consider, above all things, how any particular habit bears upon the human constitution, and to state what is the result of his inquiries, however irreconcilable it may be with popular prejudice or practice.

'The primary effect of all distilled and fermented liquors,' says Dr Combe, 'is to *stimulate the nervous system and quicken the circulation.*' They may thus be said to have a larger measure of the effect which animal food has upon the system. It is therefore the less surprising that those tropical nations which live most on farinaceous diet are also found to be those which have the least propensity to the drinking of ardent spirits; while those northern nations which live most on animal food have the exactly contrary inclination with respect to liquor, the Scandinavian tribes being notoriously the greatest sots that have ever been known. Dr Combe admits that in some conditions of the system, when the natural stimulus is defective, it may be proper to take an artificial supply in the form of ardent and fermented liquors. 'There are,' he says, 'many constitutions so inherently defective in energy as to derive benefit from a moderate daily allowance of wine; and there are many situations in which even the healthiest derive additional security from its occasional use. If, for example, a healthy person is exposed to unusual and continued exertion in the open air, or to the influence of anxious and depressing watchfulness, a moderate quantity of wine with his food may become the means of warding off actual disease, and enabling him to bear up uninjured, where without it he would have given way.' But Dr Combe at the same time declares, in the most decided language, that when the digestion is good, and the system in full vigour, the bodily energy is easily sustained by nutritious food, and 'artificial stimulant *only increases the wasting of the natural strength.*' Nearly all physicians, indeed, concur in representing ardent liquors as unfavourable to the health of the healthy, and as being, in their excess, highly injurious. Even the specious defence which has been set up for their use, on the ground that they would not have been given to man if they had not been designed for general use, has been shewn to be ill-founded, seeing that *vinous fermentation*, from which they are derived, is not a healthy condition of vegetable matter, but a stage in its progress to decay. Upon the whole, there can be little doubt that these liquors are deleterious in our ordinary healthy condition; and that pure water, toast-water, milk, whey, and other simple and unexciting beverages, would be preferable —the first being the most natural—if we could only consent to deny ourselves further indulgence.

CLEANLINESS.

To keep the body in a cleanly condition is the third important requisite for the preservation of health. This becomes necessary, in consequence of a very important natural process which is constantly going on near and upon the surface of the body.

The process in question is that of *perspiration.* The matter here concerned is a watery secretion, produced by glands near the surface of the body, and sent up through the skin by channels imperceptibly minute and wonderfully numerous. From two to six pounds of this secretion are believed to exude through these channels or *pores* in the course of twenty-four hours, being, in fact, the chief form taken by what is called the waste of the system, the remainder passing off by the bowels, kidneys, and lungs. To promote the free egress of this fluid is of the utmost importance to health; for when it is suppressed, disease is ready to fall upon some of the other organs concerned in the discharge of waste.

One of the most notable checks which perspiration experiences is that produced by a current of cold air upon the skin, in which case the pores instantly contract and close, and the individual is seized with some ailment either in one of the other organs of waste, whichever is in him the weakest, or in the internal lining of some part of the body, all of which is sympathetic with the condition of the skin. A result of the nature of that last described is usually recognised as a cold or catarrh. We are not at present called on particularly to notice such effects of checked perspiration, but shall allude to others of a less perceptible, though not less dangerous nature.

The fluid alluded to is composed, besides water, of certain salts and animal matters, which, being solid, do not pass away in vapour, as does the watery part of the compound, but rest on the surface where they have been discharged. There, if not removed by some artificial means, they form a layer of hard stuff, and unavoidably impede the egress of the current perspiration. By cleanliness is merely meant the taking proper means to prevent this or any other extraneous matter from accumulating on the surface, to the production of certain hurtful consequences.

Ablution or washing is the best means of attaining this end; and accordingly it is well for us to wash or bathe the body frequently. Many leave by far the greater part of their bodies unwashed, except, perhaps, on rare occasions, thinking it enough if the parts exposed to common view be in decent trim. If the object of cleaning were solely to preserve fair appearances, this might be sufficient; but the great end, it must be clearly seen, is to keep the skin in a fit state for its peculiar and very important functions. Frequent change of the clothing next to the skin is of course a great aid to cleanliness, and may partly be esteemed as a substitute for bathing, seeing that the clothes absorb much of the impurities, and, when changed, carry off what they have absorbed. But still this will not serve the end nearly so well as frequent ablution of the whole person. Any one neglecting this will be convinced of the fact on going into a bath and using the flesh-brush in cleansing his body. The quantity of scurf and impurity which he will then remove, from a body which has changes of linen even once a day, will surprise him.

Considering the importance of personal cleanliness for health, it becomes a great duty of municipal rulers to afford every encouragement in their power to the establishment of public baths for the middle and working classes, and to extend and protect all existing facilities for washing clothes, as well as for private supplies of water. Baths should neither be very cold nor very warm, but in an agreeable medium; and they should never be taken within three hours after a meal. Nature may be said to make a strong pleading for their more general use, in the remarkably pleasing feeling which is experienced in the skin after ablution.

EXERCISE.

The constitution of external nature shews that man was destined for an active existence, as without labour scarcely any of the gifts of Providence are to be made available. In perfect harmony with this character of the material world, he has been furnished with a muscular and mental system, constructed on the principle of being fitted for exertion, and requiring exertion for a continued healthy existence. Formed as he is, it is not possible for him to abstain from exertion without very hurtful consequences.

Muscular Exercise.

With regard to merely bodily exercise, it is to be observed, in the first place, that we have no fewer than four hundred muscles, each designed to serve some particular end in locomotion, or in operating upon external objects. A sound state of body depends very much upon each of these muscles being brought into action in proper circumstances and to a suitable extent. There is even a law, operating within a certain range, by which each muscle will gain *in strength and soundness* by being brought into a proper degree of activity.

The process of waste and renovation may be said to be always going on in the body, but it does not go on with permanent steadiness unless the muscular system be exercised. Whenever one of the organs is put into exertion, this process becomes active, and the two operations of which it consists maintain a due proportion to each other.

It is of the utmost importance to observe that the exercise of any particular limb does little besides improving the strength of that limb; and that, in order to increase our general strength, the whole frame must be brought into exercise. The blacksmith, by wielding his hammer, increases the muscular volume and strength of his right arm only, or if the rest of his body derives any advantage from his exercise, it is through the general movement which the wielding of a hammer occasions.

That bodily exercise may be truly advantageous, the parts must be in a state of sufficient health to endure the exertion. A system weakened by disease or long inaction must be exercised very sparingly, and brought on to greater efforts very gradually, otherwise the usual effects of over-exercise will follow. In no case must exercise be carried beyond what the parts are capable of bearing with ease; otherwise, a loss of energy, instead of a gain, will be the consequence.

Kinds of Bodily Exercise.

Exercise is usually considered as of two kinds—active and passive. The active consists in walking, running, leaping, riding, fencing, rowing, skating, swimming, dancing, and various exercises, such as those with the poles, ropes, &c. prescribed in gymnastic institutions. The passive consists in carriage-riding, sailing, friction, swinging, &c. (For various modes of agreeable recreation, see articles on INDOOR and OUTDOOR AMUSEMENTS, vol. ii.)

Walking is perhaps the readiest mode of taking exercise, and the one most extensively resorted to. If it brought the upper part of the body as thoroughly into exertion as the lower, it would be perfect, for it is gentle and safe with nearly all except the much debilitated. To render it the more effectual in the upper part of the body, it were well to walk at all times, when convenient, *singly*, and allow the arms and trunk free play. It is best to walk with a companion, or for some definite object, as the flow of nervous energy will be by these means promoted, and the exercise be rendered, as has been already explained, the more serviceable.

Very long or rapid walks should not be attempted by individuals of sedentary habits, nor by weakly persons. Their frames are totally unprepared for such violent exertion. When a person who has been long confined at still employments, finds himself at liberty to indulge his inclination for a ramble of a few days in the country, he should begin with slow and short marches, and be content therewith till his body is hardened for greater efforts. This is a rule followed in the army with respect to regiments which are about to undertake long marches. Every summer, many youths, from ignorance, do themselves great injury, by undertaking pedestrian excursions much beyond their strength. Jaded to the last degree, and incapable of enjoying anything presented to their observation, they nevertheless persist in making out some appointed number of miles per day, never once thinking of the outrage they are committing upon themselves, and only looking to the glory of executing their task, the only pleasure they find in the journey. Serious consequences—consumption not unfrequently—follow such ill-advised efforts.

Running.—Although this and other gymnastic exercises—such as leaping, wrestling, throwing heavy weights, &c.—may, when judiciously had recourse to, invigorate the body, yet, from apprehension of the evils and accidents which may be so occasioned, young persons ought not to be permitted to engage extensively in such exercises, except under the care of some one well acquainted with gymnastics.

Fencing is, of all active exercises, that which is the most commendable, inasmuch as it throws open the chest, and at the same time calls into action the muscles both of the upper and lower extremities. Add to this that it improves very much the carriage of the body; for which reason it may be reckoned a branch of polite education. The salutary effects of the other exercises which are taught in gymnastic institutions—such as exercise with the ropes, poles, pulleys, &c.—have been demonstrated by the marked increase in the weight and strength of the body which takes place in a given time during the employment of these exercises.

Dancing is exhilarating and healthful, and seems to be almost the only active exercise which the despotic laws of conventionality permit young ladies to enjoy. We can scarcely consider modern quadrilles, elegant though they be, as exercise, seeing that they differ little from the most common walking movements. But country-dances, reels, and hornpipes are genuine exercise, and their less refinement may be considered as amply compensated by the superior benefit which they are calculated to confer upon health.

Riding is generally classed among the passive exercises, but in reality it is one which involves much action of the whole frame, and as such is very useful. Pursued solitarily, it has the drawback of being somewhat dull; but when two or three ride in company, a sufficient flow of the nervous energy may be obtained.

The amount of bodily exercise which should be taken must vary according to the habits, strength, and general health of the individual. It was an aphorism of Boerhaave, that every person should take at least two hours' exercise in the day; and this may be regarded as a good general rule.

Mental Exercise.

Having thus explained the laws and regulations by which exercise may be serviceable to the physical system, we shall proceed to shew that the same rules hold good respecting the mental faculties. These, as is generally allowed, however immaterial in one sense, are connected organically with the brain—a portion of the animal system nourished by the same blood, and regulated by the same vital laws, as the muscles, bones, and nerves. As, by disuse, muscle becomes emaciated, bone softens, blood-vessels are obliterated, and nerves lose their natural structure; so by disuse does the brain fall out of its proper state and create misery to its possessor; and as, by over-exertion, the waste of the animal system exceeds the supply, and debility and unsoundness are produced, so by over-exertion are the functions of the brain liable to be deranged and destroyed. The processes are physiologically the same, and the effects bear an exact relation to each other. As with the bodily powers, the mental are to be increased in magnitude and energy by a degree of exercise measured with a just regard to their ordinary health and native or habitual energies. Corresponding, moreover, to the influence which the mind has in giving the nervous stimulus so useful in bodily exercise, is the dependence of the mind upon the body for supplies of healthy nutriment. And, in like manner with the bodily functions, each mental faculty is only to be strengthened by the exercise of itself in particular. Every part of our intellectual and moral nature stands, in this respect, exactly in the same situation with the blacksmith's right arm—each must be exercised for its own sake.

The fatal effects of the disuse of the mental faculties are strikingly observable in persons who have the misfortune to be solitarily confined, many of whom become insane, or at least weak in their intellects. It is also observable in the deaf and blind, among whom, from the non-employment of a number of the faculties, weakness of mind and idiocy are more prevalent than among other people. This is indeed a frequent predisposing cause of every form of nervous disease.

The loss of power and health of mind from imperfect or partial exercise of the faculties, is frequently observable in the country clergy, in retired merchants, in annuitants, in the clerks of public offices, and in tradesmen whose professions comprehend a very limited range of objects. There is no class, however, in whom the evil is more widely observable than in those females who, either from ignorance of the laws of exercise, or from inveterate habit, spend their lives in unbroken seclusion, and in the performance of a limited range of duties. All motive is there wanting. No immediate object of solicitude ever presents itself. Fixing their thoughts entirely on themselves, and constantly brooding over a few narrow and trivial ideas, they at length approach a state little removed from insanity, or are only saved from that, perhaps, by the false and deluding relief afforded by stimulating liquors. In general, the education of such persons has given them only a few *accomplishments*, calculated to afford employment to one or two of the minor powers of the mind, while all that could have engaged the reflecting powers has been omitted. Education, if properly conducted, would go far to prevent these evils.

On the other hand, excessive exercise of the brain, by propelling too much blood to it, and unduly distending the vessels, is equally injurious with its disuse. And not only are fatal effects to be apprehended from undue mental task-work, but also from that constant *stretch* of the mind which attends an unduly anxious and watchful disposition. The ancients had some notion of the impropriety of an incessant exertion of the mind, and rebuked it by their well-known proverb—*Apollo does not keep his bow always bent.* But they had comparatively little experience of the oppressive mental labours endured by large portions of modern society. Irrational, and in some respects dangerous, as many of the habits of our ancestors were, it is questionable if they suffered so much from these causes as their successors do from virtuous but overtasking exertion. To maintain what each man conceives to be a creditable place in society, now requires such close and vigorous exertions, that more, we verily believe, perish in the performance of duties in themselves laudable, than formerly sank under fox-hunting, toast-drinking, and the gout.

It is in large cities that this unintentional kind of self-destruction is most conspicuously exemplified. And it is in London, above all other places, that the frenzy is to be observed in its most glaring forms. To spend nine hours at a time in business, without food or relaxation, is not only not uncommon, but an almost universal practice, among the citizens of London: from a breakfast at eight to a chop at five, they are never, to use an expressive phrase, *off the stretch.* Upon a stomach enfeebled by exhaustion, they then lay the load of a full meal, which perfect leisure would hardly enable them to digest. But far from waiting to digest it, they have no sooner laid down knife and fork, than away they must once more rush to business—not perhaps willingly, for nature tells them that it would be agreeable to rest; but then—but then business *must* be attended to. If nature were to punish the daily transgression by the nightly suffering, we should find few who, for the sake of pecuniary gain, would thus expose themselves to misery. But she runs long accounts with her children, and, like a cheating attorney, seldom renders her bill till the whole subject of litigation has been eaten up. Paralysis at fifty comes like the mesne process upon the victim of commercial enthusiasm, and either hurries him off to that prison from which there is no liberation, or leaves him for a few years organically alive to *enjoy* the fruits of his labours.

The absurdity of an ignorance or weakness of this kind is perhaps still more striking when it occurs in individuals who make the acquisition of knowledge the chief aim of life. As the world is at present situated, it is possible to acquire learning upon almost every subject, and an infinite amount of knowledge, useful and otherwise, without even by chance lighting upon a knowledge of the most indispensable observances necessary for the preservation of a sound mind in a sound body. Half of the multiform languages of Asia may be mastered, while the prodigy who boasts so much learning knows not that to sit a whole day within doors at close study is detrimental to health; or, if he knows so much, deliberately prefers the course which leads to ruin.

The premature extinction of early prodigies of genius is generally traceable to the same cause. We read that, while all other children played, they remained at home to study; and then we learn that they perished in the bud, and balked the hopes of all their admiring friends. The ignorant wonder is of course always the greater when life is broken short in the midst of honourable undertakings. We wonder at the inscrutable decrees which permit the idle and dissolute to live, and remove the ardent benefactor of his kind, the hope of parents, the virtuous, and the self-devoted; never reflecting that the highest moral and intellectual qualities avail nothing in repairing or warding off a decided injury to the physical system, which is regulated by laws of a different, but of as imperative a nature. The conduct of the Portuguese sailors in a storm, when, instead of working the vessel properly, they employ themselves in paying vows to their saints, is just as rational as most of the notions which prevail on this subject in the most enlightened circles of British society.

It ought to be universally known, that the uses of our intellectual nature are not to be properly realised without a just regard to the laws of that perishable frame with which it is connected; that, in cultivating the mind, we must neither overtask nor undertask the body, neither push it to too great a speed, nor leave it neglected; and that, notwithstanding this intimate connection and mutual dependence, the highest merits on the part of the mind will not compensate for muscles mistreated, or soothe a nervous system which severe study has tortured into insanity. To come to detail—it ought to be impressed on all that to spend more than a moderate number of hours in mental exercise, diminishes insensibly the powers of future application, and tends to abbreviate life; that no mental exercise should be attempted immediately after meals, as the processes of thought and of digestion cannot be safely prosecuted together; and that without a due share of exercise to the whole of the mental faculties, there can be no soundness in any, while the whole corporeal system will give way beneath a severe pressure upon any one in particular. These are truths completely established

with physiologists, and upon which it is undeniable that a great portion of human happiness depends.

Sleep.

It may be laid down as an axiom, that the more uninterrupted sleep is, the more refreshing and salutary will be its effects; for, during this period, the body undoubtedly acquires an accession of nervous energy, which restlessness, however induced, must disturb; and therefore the state of the body before going to sleep, the kind of bed, and the manner of clothing, require especial attention. As the functions of the body are performed more slowly during our sleeping than our waking hours, a full meal or supper taken immediately before going to bed imposes a load on the stomach which it is not in a condition to digest, and the unpleasant consequence of oppressive and harassing dreams is almost certain to ensue. When the sleeper lies upon his back, the heart pressing, while pulsating, on the stomach, gives rise to a sense of intolerable oppression on the chest, which seems to bear down upon the whole body, so that in this painful state not a muscle will obey the impulse of the will, and every effort to move appears to be altogether unavailing. This constitutes *incubus* or *nightmare;* and it may be observed that, as acidity on the stomach, or indigestion, gives rise to such dreams, so all dreams of this disturbed character are converse indications of indigestion; for which reason, the great physiologist Haller considered dreaming to be a symptom of disease. It is certain that the dreams of healthy persons are the lightest and most evanescent.

The kind of bed on which we repose requires attention. Some are advocates for soft, others for hard beds; hence some accustom themselves to feather-beds, others to mattresses. The only difference between a soft and a hard bed is this—that the weight of the body in a soft bed presses on a larger surface than on a hard bed, and thereby a greater degree of comfort is enjoyed. Parents err in fancying that a very hard bed contributes to harden the constitution of their children; for which reason they lay them down on mattresses, or beds with boarded bottoms. A bed for young children cannot be too soft, provided the child does not sink into it in such a manner that the surrounding parts of the bed bend over and cover the body. The too great hardness of beds, says Dr Darwin, frequently proves injurious to the shape of infants, by causing them to rest on too few parts at a time; it also causes their sleep to be uneasy and unrefreshing.

When in bed, the head should be always higher than the feet; and those subject to palpitation of the heart should lie with their heads considerably higher. Night-clothes should never consist of more than a chemise or shirt of cotton or linen. It is also highly improper to sleep in a bed overloaded with clothes; the body is thereby heated, and feverishness and restlessness induced. Accordingly, persons who complain of sleeplessness should look to the quantity of their bed-clothing; for the unnecessary addition of a single blanket may be the sole cause of the annoyance. It is also imprudent to lie with the head entirely within the bed-clothes; for in this case the same air which has been already breathed must be again and again inhaled. For the same reason, the curtains, if used at all, should not be drawn closely round the bed. Washing the face and hands, and brushing the teeth, before going to bed, will be found to contribute materially to comfort. Whatever be the time chosen for sleep, it is evident that no person can with impunity convert day into night. Eight o'clock for children, and eleven for adults, may be recommended as good hours for retiring to rest. It is well known that children require more sleep than adults; and more sleep is requisite in winter than in summer. The average duration of sleep which may be recommended for adults is *eight* hours; but much depends upon habit, and many persons require only six. On leaving the bed-room, the windows should be opened, and the clothes of the bed turned down, in order that the exhalations of the body during sleep may be dissipated. If, instead of this, the bed be made immediately after we have risen, these exhalations are again folded up with the clothes—a practice which is not consonant either with cleanliness or with health.

TEMPERATURE.

The fifth important requisite for health is, that the body be kept in a temperature suitable to it.

The degree of heat indicated by 64 degrees of Fahrenheit's thermometer, or that of a temperate summer day, is what the human body finds it agreeable to be exposed to when in a state of inactivity. In air much colder, the body experiences an unpleasant sensation, unless some warm clothing be worn, or a pretty active exercise indulged in. When, either by natural or artificial means, the body is kept in a suitable state of warmth, the functions of the circulation and perspiration in the skin go on healthily; it is red, in consequence of the blood being urged into the capillaries or minute vessels near the surface; it is also soft and moist, from the action of the glands for secreting the waste fluid and its free egress through the pores. This is a condition of great comfort; and the appearance of those who enjoy it, conveys to others the notion that they are in good health. When, on the contrary, there is a much lower temperature, the functions of the vessels connected with the skin are liable to be considerably deranged. The vessels in these circumstances, contract; the blood is driven inwards, where it sometimes occasions diseases of a dangerous nature; the perspiration also being prevented from passing out by its usual channels, catarrhal complaints ensue, sometimes ending in consumption.

It is of the more importance to make these facts generally known, as a notion prevails that exposure to a painful degree of cold tends to induce hardiness of constitution and to promote health. Undoubtedly, there may be harm from an opposite extreme, and we know well that excessive clothing and living in overheated apartments are detrimental to health. But safety lies in a medium between the two extremes. There is a degree of warmth which is both agreeable and healthy, and which it is desirable to have around us as constantly as possible—generally from 60 to 64 degrees Fahrenheit.

There is no period of life at which warmth is of more consequence than in infancy. In a very young babe, the circulation is almost altogether

confined to the surface, the internal organs being as yet in a very weak state. In such circumstances, to plunge the child into cold water, from an idea of making it hardy, as is customary in some countries, and among ignorant persons in our own, is the height of cruelty and folly; for the unavoidable consequence is, that the blood is thrown in upon the internal organs, and inflammation, bowel-complaints, croup, or convulsions, are very likely to ensue. A baby requires to be kept at a temperature above what is suitable to a grown person; it should be warmly, but not heavily clothed; the room where it is kept should be maintained at a good, but not oppressive heat; and it should never be put into other than tepid water. It should not be exposed to the open air for some days after its birth.

At all periods of life, it is most desirable to avoid exposure to very low temperatures, especially for any considerable length of time. To sit long in cold school-rooms or work-rooms, with the whole body, and especially the feet, in a chilled condition, is very unfavourable to the health of young people. It is not possible that a condition so adverse to the healthy action of the cutaneous vessels should not lead, if long persisted in, to very bad consequences. Those who are compelled to be sedentary, should make it their endeavour to obtain a sufficiently high temperature, either by warming their apartments sufficiently, or thickening their clothing. Common fires, though delightful from their cheerful look, are confessedly very inadequate, in most circumstances, to heat large work-rooms, school-rooms, or even the larger class of sitting-rooms; not to speak of the great objection which has been made to them on the score of economy, three-fourths of their heat being sent off through the chimney. It is most desirable that some means in which the public could have confidence were devised for thoroughly, and at the same time healthily, warming large apartments. Stoves inclosed in large iron-plate cases (Arnott's stoves), pipes of hot water or of steam, and blasts of heated air, are amongst the most conspicuous plans tried within the last few years. (See WARMING, No. 31.)

Clothing should be in proportion to the temperature of the climate and the season of the year; and where there are such abrupt transitions from heat to cold as in our own country, it is not safe ever to go very thinly clad, as we may in that case be exposed to a sudden chill before we can effect the proper change of dress. Very fatal effects often result to ladies from incautiously stepping out of heated rooms in the imperfect clothing which they ludicrously style *full-dress:* all such injuries might be avoided by putting on a sufficiency of shawls or cloaks, and allowing themselves a little time in the lobby to cool. The under-clothing in this country should be invariably of flannel, which is remarkably well calculated to preserve uniformity of temperature, as well as to produce a healthy irritation in the skin. While the value of comfortable clothing is fully acknowledged, we should never lose sight of the value of exercise for keeping up a kindly glow upon the surface, and for the support of a high tone of general health. Any one who, neglecting this, should live constantly in a warm apartment, or only go out of doors muffled up in a mass of clothing, would speedily suffer from a relaxed state of the system, and become so susceptible of damage from the slightest change of temperature in the atmosphere, that the most dangerous consequences might be apprehended.

Wet clothes applied to any part of the body, when it is in an inactive state, have an instantaneous effect in reducing the temperature, this being an unavoidable effect of the process of evaporation which then takes place. Hence it is extremely dangerous to sit upon damp ground, or to remain at rest for a single minute with wetted feet, or any other part of the body invested in damp garments. Dampness in the house in which we live has the same effect, and is equally dangerous. The chill produced by the evaporation from the wetted surface checks the perspiration, and sends the blood inwards to the vital parts, where it tends to produce inflammatory disease. Few persons seem to be aware of these truths. We find young men heedlessly getting their feet wet, and sitting with them in that condition, thereby incurring the most deadly peril. Young women commit a similar folly when they walk out in thin shoes in a wet or cold day. Exposure to wet, damp, or cold, is of comparatively little moment when the body, by a course of exercise or training, has been prepared to endure these conditions. Thus a person brought up delicately, or much within doors, would be killed by that which would have little or no effect on a ploughman.

Errors in Dress.

This is perhaps the most appropriate place in which to introduce some remarks upon errors in dress. The integuments which nature calls upon us to put on for the sake of warmth, are too often made the means of inflicting serious injury, either through ignorance, fashion, or caprice. It is therefore necessary, in a treatise on the preservation of health, to advert in emphatic terms to this subject.

It is scarcely too much to say that there is no part of the human frame, from the sole of the foot to the crown of the head, which has not been, and is not at this moment, mistreated by fashion. We laugh at the Chinese ladies, who have their feet constrained by iron moulds into mere bulbous appendages to the limbs; but we never reflect that, amongst ourselves, errors only inferior in degree are constantly committed. The foot naturally spreads out, fan-like, from the heel to the toes. But instead of having our shoes formed in the same triangular shape, they are made in a lozenge form, truncated at the front, the toes being thus perverted from their radiating arrangement into one exactly the opposite; so that they become crushed under one another, and deprived of a great part of that muscular power by which they were designed to propel our bodies in walking. In the greater height usually given to the heels of shoes, another important deviation from nature is committed. When the heel is raised above the level of the ball of the foot, a complete derangement takes place in the muscles of locomotion; the power of the limb is impaired; and the whole body is thrown off its equipoise. It is impossible, in such circumstances, to exercise the body as it ought to be. The foot is also forced or plugged down into the narrow front of the shoe, where the toes become liable to the grievance of corns. Thus the free healthy play of the various

parts of the body is further diminished. From the uneasiness and constraint experienced in the feet, sympathetic affections of a dangerous kind often assail the stomach and chest. Low-heeled shoes, with a sufficiency of room for the toes, would completely prevent all such consequences.

An improved taste in the male sex has long since abolished the coarse and self-annoying absurdity of leathern small-clothes; but it is still too common to impede the circulation and the play of the muscles by tight apparel, especially in the regions of the stomach and neck. The immediate effect of these injudicious appliances is much inconvenience; the remote result is a diminution of the general strength and health. But all the errors of the male sex sink into insignificance when compared with one to which the fair are liable. In the construction of the human chest and abdomen, nature has provided ample room for several important viscera, the functions of which cannot be in any degree disturbed without a wrong being inflicted upon the whole system. Here reside the heart, the lungs, the liver, and the stomach. Fine ladies may affect to shut their mind's eye to the existence of such things; but the daintiest of their emotions depend upon the right state of those very viscera, without which they could no more think, speak, and act, than they could cast languishing looks without eyes, or melt our hearts by witching minstrelsy without a tongue and fingers. In order to reduce themselves to an ideal standard of girth, almost all the unmarried, and not a few of those who are otherwise, brace themselves in a greater or less degree with corsets, which produce the desired roundness and slenderness at the expense of all the internal organs upon which health depends. The false ribs are pressed inwards; the respiratory and circulatory systems are crushed and thrust out of their proper place; the alimentary system is deranged; and even upon the exterior of the person, deformities of the most glaring kind, such as humped shoulders and curved spines, are produced. Custom to a certain extent enables the victim to endure the inconvenience; there are even some who feel so little trouble from it, as to deny that any harm ensues from tight-lacing. But a violation so excessive cannot be otherwise than mischievous. We have seen a young lady's sash which measured exactly twenty-two inches, shewing that the chest to which it was applied had been reduced to a diameter—allowing for clothes—of little more than seven inches!

All who are aware of the internal organs at that part of the body, know very well that it is impossible for these to exist in their natural condition within so small a space. Bruised, impeded, and disordered, they must of course be, and accordingly cannot fail to become a source of dreadful suffering to the wretched being who outrages them. Palpitations, flushings, dyspepsy, determination of blood to the head, and consumption, are among the evils which physicians enumerate as flowing from this sacrifice to vanity. Another of a moral kind is acknowledged to be of by no means infrequent occurrence: in order to soothe the painful sensations produced by the constraint, spirituous liquors and cordials are resorted to, and thus habits of the most degrading nature are formed. Another evil still, respecting which a hint may be sufficient, is the unfitting of the system for the duties of a mother. How many domestic afflictions, which are submitted to in a spirit of resignation, as the unavoidable decrees of Providence; how many of the saddest scenes which this world ever presents—gentle and tender girls pining away under the eyes of hopeless parents—beloved wives torn from the arms of husbands and children at the very moment when prolonged life was most needful—must be owing to a cause too trivial and unworthy to be mentioned in the same sentence with its so dire effects! No doubt, it is well to submit meekly to such afflictions; but while they are ascribed in all humility to a Providence which is upon the whole only another term for Mercy and Justice, let us not be blind to the fact, that they accrue through violations committed by ourselves upon laws established by Providence for our happiness, and might have been avoided by a different course of conduct.

The fashion of tight-lacing obviously owes its origin to a desire on the part of the ladies to attract admiration. It is of little importance to point out that they are quite wrong in their calculations as to the effect; but we would press upon the guilty parties, and all interested in their welfare, that tight-lacing is a practice which cannot be long persisted in without the most disastrous consequences. It is painful to reflect that in some instances, parents, so far from discouraging the practice, are so ignorant as to force it upon their children. We have heard of a young lady whose mother stood over her every morning with the engine of torture in her hand, and, notwithstanding many remonstrative tears, obliged her to submit to be laced so tightly as almost to stop the power of breathing. The result is, that the unfortunate victim is now severely afflicted with asthma, and has fallen into a state of low health. As a general rule, it cannot be too strongly impressed upon those who have the care of young persons, that all clothing should sit lightly upon the figure, so as to allow of the full play of every part of the system.

INNOCENT ENJOYMENTS.

A sufficiency of innocent enjoyments has been set down as the sixth requisite towards the preservation of health. It may seem almost superfluous to treat this part of the subject, since the disposition to take amusement is one by no means generally wanting. A regard, however, for the completeness of our little treatise induces us to make a few remarks on it; and we are not satisfied that there is not a considerable number of persons to whom an injunction to take innocent enjoyments is needful. There may be some advantage, therefore, in seeing the matter placed on something like a philosophical basis.

No physiological doctrine seems more entitled to faith and regard, than that a harmonious exercise, in moderation, of all parts of the system, including the organs of the mental faculties, is necessary for health. It is proved by the very craving which we experience, after a long task, or a long perseverance in some particular habits, for something which will engage a different set of faculties. There is nothing which will pleasingly engage our thoughts for any considerable length of time.

Something inferior will invariably be preferred, if it only be new. Now, the duties by which men in general earn their subsistence are in all cases of such a nature as only to call into exercise a part of their mental and bodily system. Something is required at once to soothe and compensate us for the drudgery of our current labours, and to bring into exercise those parts of our muscular frame and intellect which professional duty has left unoccupied. To begin with a humble illustration: how delightful to a tailor, after long exercising his fingers and arms alone at his business, to enter into some athletic sport upon the village-green, by which his limbs also will be exercised! After a lawyer has fagged for a day at a brief, how delightful to be able, by the reading of a new novel or play, to call up another set of the intellectual powers! In these changes from grave to light occupation, there is at once repose given to the tasked faculty, and the gratification of employment given to others which have been pining for want of something to do.

Amongst amusements, *reading* takes a most distinguished place; for there is none which may be more readily or more innocently indulged in, and fortunately, in our own country, it is one which may now be enjoyed by all.

Next to reading stands *music*, a means of enjoyment of which only a few, comparatively, in our country take advantage, but which might easily be made much more extensively available, and probably will be so in the course of a few years. Connected intimately with music is *dancing*, which is not only a cheerful amusement, but a positive and direct means of bodily exercise. A family musical or dancing scene, like a family reading scene, is a thing beautiful to look upon. There is a prejudice against both in some minds, on account of their being liable to abuse; but the abuses of both arise very much from their not being extensively or freely indulged in. Were music the general accomplishment which it might easily be made, it would not only be indulged in on all occasions with simplicity and innocence, but it would supplant coarser and more clandestine amusements. Dancing is the nightly amusement of the French peasantry, and it has never been pretended that these people are less virtuous than the corresponding class in our own country. *Theatrical representations* it might be more difficult to place on such a footing as to secure the unhesitating approbation of the good; but certainly if this were done, they might prove highly serviceable in furnishing amusement.

In the class of amusements we must reckon meetings or promenades in ornamental grounds, excursions into the country, and little tours, all of which are highly commendable in those who are able to indulge in them. The entertainment of little parties of friends, and the going out to entertainments given by them in return, are other means of amusement common in society, and which may be moderately indulged in with much advantage. In short, whatever gives a pleasant variation to the monotony of life, without leading the mind away from duty or corrupting the manners, ought to be indulged in as freely as circumstances will permit. The mind returns from such diversions with renewed tone and power, and neither the time nor the expense is lost in the long-run. It is the more necessary to impress these maxims, as many well-meaning persons, alarmed perhaps at the occasional abuse of such enjoyments, repudiate them nearly altogether, and thereby lower the tone of their health, both as respects the body and the mind. It is particularly distressing to see such persons exercising a control over the young, and denying to their unfortunate protégés an element of life not much less pressingly necessary than the air they breathe. (See INDOOR AMUSEMENTS.)

Enjoyments are of many kinds. Some are sensual, as the taking of agreeable food; others are intellectual, as agreeable music, reading, &c.; others are moral, as the exercise of philanthropy, the religious feelings, &c.; and some are sympathetic, and consist in the exercise of the affections, and the reflection of that gratification which we have endeavoured to impart to others. We may consider as such all things over and above the plainest unrelished fare, and the supply of water, air, and a barely sufficient temperature. These are usually considered as strictly the *necessaries* of life, the others being the comforts or luxuries. The distinction is not quite correct. The first class are certainly immediately necessary to the support of life; that is to say, they are hourly, daily necessary. But more or less of what are called the comforts of life are also necessary, if we would preserve health. The only difference is, that the want of them would not tell in so short a time as the want of the so-called necessaries. If a human being be shut up in a cell, and allowed only a sufficiency of unrelished and unvaried food, with air and water, the want of all the enjoyments of life, sensual, intellectual, moral, and sympathetic, will, in a certain time, make him utterly miserable; the health of body and mind will give way; and if the experiment be sufficiently protracted, he will perish. The ignorance which prevails on this point led to the trial of what is called the *silent system* in prisons, which has been abandoned as utterly irreconcilable with humanity. It were well if more knowledge prevailed on the subject, for, from erroneous ideas of what is *necessary* for healthy life, many deprive themselves or others of things which, when we take the element of time into account, are as essential to health as the supply of the air we breathe. There is, in some enthusiastic minds, a spirit of asceticism and self-mortification which would give up all the enjoyments of life together. Such persons rarely fail to reduce their own health, if they do not also exercise some unhappy control to the same effect over their fellow-creatures. While self-denial for moral purposes is always admirable, and over-indulgence of every kind saps the vigour and fortitude of the human character, it should be ever kept in view that there is great danger in reducing the allowance of comforts and indulgences too low. Very rigid views of what is necessary for the support of life usually prevail, wherever the affluent have to dictate a style of living for the poor. The tendency there is, to reduce allowances as nearly as possible to what may be called the *immediate necessaries*; for it does not seem just or right that paupers, adults or children, should enjoy any species of gratification. But these are short-sighted views. The health of these unfortunate persons requires something more, and this something would be granted by an enlightened humanity. We have a strong

manifestation of this need in the eagerness with which paupers generally desire allowances of tea or tobacco, or, indeed, the least variation of their diet. The craving for these luxuries is not so much, what it is generally thought solely to be, the result of bad habits long indulged in, as it is the expression of a want in the personal economy—a want which, by one means or another, must be supplied, or injurious consequences will ensue.

EXEMPTION FROM HARASSING CARES.

It is little more than a repetition of doctrines already laid down, that, for the due preservation of health, a human being requires an exemption from acute distress of mind and harassing cares.

Mental distress and anxiety operate through the brain upon the condition of the whole body, and, when long protracted, effectually undermine the health. 'It is impossible,' says Dr S. Smith, 'to maintain the physical processes in a natural and vigorous condition, if the mind be in a state of suffering. Every one must have observed the altered appearance of persons who have sustained calamity. A misfortune that struck to the heart happened to a person a year ago; observe him some time afterwards—he is wasted, worn, the miserable shadow of himself; inquire about him at the distance of a few months—he is no more.' It is Dr Smith's opinion that the nearest cause of many suicides is not strictly a desire to escape from a state of suffering, but some disease, probably inflammation of the brain, brought on by distress of mind. 'By a certain amount and intensity of misery, life may be suddenly destroyed; by a smaller amount and intensity, it may be slowly worn out and exhausted. The state of the mind affects the physical condition; the continuance of life is wholly dependent on the physical condition; it follows that, in the degree in which the state of the mind is capable of affecting the physical condition, it is capable of influencing the duration of life.'

Depression of mind, besides its immediate effect on the nervous system, deranges the respiration, and mars the proper oxygenation and circulation of the blood. A diminished vitality is the consequence, often leading to pulmonary consumption. An excessive agitation and alarm of the selfish feelings, such as takes place in some minds on the approach of an epidemic, affects the whole system in such a way as—to use an expressive phrase of Dr Combe—'places it on the brink of disease;' and hence the notoriously great liability of persons in this state of alarm and apprehension to fall victims to the malady when it comes. It has been remarked that an army in a high state of confidence and cheerfulness after a victory, has a much smaller proportion of sick than in the opposite circumstances, or even in its ordinary condition. The usual proportion of sick in a garrison quartered, during peace, in a healthy country, is five per cent.; during a campaign, when there is more anxiety of mind, it is ten; in the event of defeat, although the circumstances be otherwise not unfavourable, the proportion rises to a much higher amount. It is a very instructive fact, that in a large detachment of the French army cantoned in Bavaria immediately after the battle of Austerlitz, the proportion of sick was little more than *one* per cent.

GENERAL OBSERVATIONS.

The fundamental principle of every effort to improve and preserve health has been thus stated: 'Man, as an organised being, is subject to organic laws, as much as the inanimate bodies which surround him are to laws mechanical and chemical; and we can as little escape the consequences of neglect or violation of those natural laws, which affect organic life through the air we breathe, the food we eat, and the exercise we take, as a stone projected from the hand, or a shot from the mouth of a cannon, can place itself beyond the bounds of gravitation.' To this it may be added, that 'all human science, all the arts of civilised man, consist of discoveries made by us of the laws impressed upon nature by the Author of the universe, and the applications of those laws to the conditions—which are laws also—in which man and the particular bodies and substances around him are placed; nor, it is manifest, should any science concern us more than that which relates to the conditions on which organic life is held by each individual.'

The preceding sections are but explanations, such as we have been able to afford, of the conditions under which the organic frame of man exists, and the agencies, internal and external, which operate upon it, for the maintenance of health, or the introduction of disease. It must be evident, where there is a conviction of the truth of the fundamental doctrine, that individuals and societies have their health very much at their own disposal, that a careful avoidance, on the one hand, of what is noxious, and a judicious attention to what is beneficial, are what are chiefly necessary for the preservation of the human frame in health to old age; and that premature deaths, over and above those which result from unforeseen casualties, instead of being, as supposed by the untutored mind, a mysterious and irreversible decree of Providence, are simply the natural effect of our own violation of laws which Providence has appointed for our welfare. It might still be objected, that human nature is such, that the due obedience and observance of those natural ordinances are not to be expected; so that the vast quantity of disease, and the great number of premature deaths, which afflict our present state of being, are equally to be regarded as things immutable, and therefore to be tranquilly submitted to. But this view would not be less a mistaken one; for there is no fact more clearly ascertained, than that disease and premature death are not, and never have been, fixed at any given amount, but yield constantly to the power of any new conditions which man may be able to introduce. Regarding clear views on this subject as of great importance, we shall here enter a little into detail.

The object is, we apprehend, to shew that sickness and mortality vary both in place and in time, according to physical and organic conditions.

Inquiries into these subjects were not made in ancient times; but during the last two hundred years, such facts have been recorded as enable us to ascertain that, in that space of time, with regard to nearly the whole of Europe, there has been a gradual improvement in health and life, in proportion to improved conditions. In Sweden, for instance, between 1756 and 1763, the annual

mortality was, for males, 1 in 33¼; for females, 1 in 35¾; whereas in the year 1800 it had diminished to 1 in 34¾ for males, and 1 in 37½ for females. From mortuary tables preserved with considerable accuracy at Geneva, it appears that at the time of the Reformation, one-half of the children born died within the sixth year; in the seventeenth century, not until the twelfth year; in the eighteenth century, not until the twenty-seventh year. By the Registrar-general's Report for 1871 (table 37, p. xciii.) the average mortality of London for 32 years, 1840–71, was 24·4 per 1000. For 1871 it was 24·6 per 1000, that is, about 1 in 40·6. Knowing that early in the seventeenth century the city was dense and ill cleaned, and that the habits of the people were not then what they are now, we cannot doubt that this great diminution of mortality is owing to the improved conditions in which human beings now live in the metropolis. Between the years 1730 and 1750, 74 of every 100 children born in London died before they were six years of age; a century later, only 31 and a fraction out of every 100 died under the same age—that is to say, the deaths of children in London were only half as numerous as they were a hundred years before. About a century ago, the mortality of the children received into the London hospitals was of astonishing amount. Though it seems scarcely credible, we have good reason to believe that, of the 2800 annually received, 2690, or *twenty-three in every twenty-four*, died before they were a year old. It was at length seen that this mortality was the effect of overcrowding, impure air, and imperfect aliment; and after an act of parliament had been procured to compel the officers to send the infants to nurse in the country, only 450 out of 2800 died in the first year. 'Now in England' (*Letter to Registrar-general by William Farr, M.D.*, Appendix to Report, 1871, p. 224), 'about 800,000 are born annually, and by the life table 119,594 of them die in the first year, some from congenital weakness and blight; but great numbers, not, I conceive, from the cruelty of their parents, but either from the necessities of their condition of life, or from their ignorance of the best modes of nursing children.' If much, therefore, has so far been done for the preservation of infant life, it seems that much yet remains to do. The experience in infantile mortality of recent years shews the following results:

Born.	Live to ages 1.	2.	3.	4.	5.	6.	7.	8.	9.	10.
513,	431,	403,	388,	379,	372,	367,	363,	360,	357,	355.

From this it will be seen that of the 513 born, 146, or 28·4 per cent. die before completing their sixth year.

The facts ascertained with regard to differences of mortality in different places are equally striking. A remarkable instance of the effect of marshes upon health is cited by M. Villermé. Formerly, the district of Vareggio, in Tuscany, was marshy, and its few miserable inhabitants were every year visited by severe agues. In 1741, floodgates were erected to keep out the sea, the marsh was dried up, and ague appeared no more. Vareggio subsequently became a populous and healthy district. The Isle of Ely is a marshy district in the east of England, and it was ascertained that of 10,000 deaths which occurred in it between the years 1813 and 1830, no fewer than 4732 were of children under ten years of age; the proportion of deaths of children under ten in all the other agricultural districts of England being only 3505, or as about 3 to 4 of the former number. Of 10,000 deaths between ten years and extreme old age in the same period, there were, of persons between ten and forty, 3712 in the Isle of Ely, and only 3142 in drier districts.

The population of England at the census of 1871 was (Registrar-general's Report, p. vii.) 22,712,266. Of these, 'nearly thirteen millions of people,' says the Registrar's Report (p. xix.) 'are comprised within districts or sub-districts wherein the chief towns are situate, and the death-rate among these in 1871 was 25 per 1000, or slightly in excess of the annual average; amongst the residue, or nearly ten millions, inhabiting the smaller towns, or scattered over the purely rural districts, the rate was 19·5, or slightly below the average. For general purposes, this comparison may be taken as giving a fair idea of the relative advantage as regards the duration of life which a residence in the country confers over one in towns; bearing in mind, of course, that there are special causes of unhealthiness in some country places, and that the towns themselves have a wide range of death-rate.'

It is now ascertained that England is more healthy than any continental country, the next to it in this respect being France. In continental cities, the annual rate of mortality is seldom less than 30 in 1000, and the rate frequently rises to 40 in 1000. In 1869 the death-rate per 1000 was, in England 22·3, in France 23·5, in Austria 28·9, and in Prussia 27·7.

Within the last few years, a great impetus has been given to the sanitary condition of the cities of the empire by the introduction of efficient drainage and of wholesome water, by the systematic removal of nuisances, and by the improvement of the dwellings of the poor. 'Hitherto,' says the Registrar-general (Report, 1871, p. vii.), 'the sanitary works of the country have been partial, and have been confined to places where the local authorities have displayed extraordinary energy; in some places, such as Manchester, Salford, and Glasgow, the water supply is good, but other grave defects counteract its results; in other places, as in South London, the water supply and the drainage have been greatly improved, with the best effects; in other districts, the main drainage has been carried out effectually, but the subsidiary drains, and the house drains, are imperfect; and the population outside drained towns is increasing rapidly, without a system of sewerage, and often with a bad water supply; dwelling-houses are still crowded; the state of the small towns, the villages, the farm-yards, and of many of the cottages, remains much as it was, and whole regions of great counties are, in 1871, in a condition as unsatisfactory as they were in 1838.

'What was wanted was administrative machinery, which will now be supplied by the new Sanitary Act to the whole country; and I shall watch with interest, and endeavour to record with impartiality the results of its operation.'

The following is a table prepared by Dr Letheby, shewing the saving of human life effected by sanitary improvements in certain English towns:

Name of Town.	Death-rate in 1000.		No. of Lives saved in 1000 per annum.
	Before Sanitary Measures.	After Sanitary Measures.	
Alnwick	35·2	28·3	6·9
Barnard Castle	33·3	25·9	7·4
Berwick	28·5	21·2	7·3
Bangor	35·1	30·9	4·2
Durham	26·0	22·7	3·3
Ely	25·6	19·3	6·3
Salisbury	32·2	27·0	5·2
St Thomas	26·9	23·0	3·9

Taking the whole of the above facts into account, we must see that not only do health and longevity depend expressly on laws the operation of which we can understand, but man has it in his power to modify to a great extent the circumstances in which he lives, with a view to the promotion of his organic wellbeing and preservation. We see that the draining of a marsh banishes the ague, that a change from city to country air diminishes mortality, and that the greater comforts possessed by the affluent secure them longer life than the poor. It may not immediately be in the power of every one to change his circumstances from the unhealthy to the healthy; but it is a great matter to know that the object is within human power, for then at least an encouragement is held out to induce each individual to make every possible effort to put himself, and to contribute to putting society in general, into more salubrious conditions.

The object may be said to depend partly upon individual, and partly upon social efforts. Every person has some control over the quantity and quality of the food he eats, the condition of the air he breathes, and the exercise, repose, and recreation which are demanded by his muscular and nervous system, according to the principles laid down in this and similar treatises; as also some power to refrain from injurious excesses, and to avoid the various external agencies of a detrimental kind which constantly beset him. Let him act as he ought to do in these respects, and he will reap an immediate reward in that pleasurable state of consciousness which attends a healthy existence. But some of the most important requisites for health depend on public measures. It unfortunately happens, in most countries, that while the bearing of certain acts upon individual happiness is fully seen and provided for, those which affect the condition of communities are imperfectly understood; so that measures destructively injurious to millions will be blindly enforced and defended by those who would severely punish the slightest wrong inflicted by one man upon another.

Some facts elicited by parliamentary inquiry, with regard to several of our principal cities, are of a most startling kind.

Dr Arnott, when examined as to the prevalence of fever in Bethnal Green, Whitechapel, Wapping, and certain other districts in the metropolis, attributed them directly to the dirty and neglected state of these localities, instancing—'Houses, courts, and alleys without privies, without covered drains, and with only open surface-gutters, so ill made, that the fluid in many cases was stagnant; large open ditches containing stagnant liquid filth; houses dirty beyond description, as if never washed or swept, and extremely crowded with inhabitants; heaps of refuse and rubbish, vegetable and animal remains, at the bottom of close courts and in corners.' [The amount of noxious matter which is allowed to collect in London is far beyond what most of its inhabitants have any conception of, as is the case with most other conditions chiefly affecting the poor.] In Manchester, 18,300 persons, or one-twelfth of the whole working population, live beneath the level of the ground, with an insufficiency of both light and air. In that town, the dwellings of labourers are often situated in narrow courts, and back to back, so as to prevent ventilation; the drains are far from sufficient; and till recently, there was not in the town one free space in which the people could enjoy the slightest recreation. In Liverpool, 39,000 persons live in cellars, dark, damp, confined, ill ventilated, and dirty. The class next above, to the number of 80,000, inhabit houses built around small courts, closely pent up, back to back, with only one entrance to each, and usually a receptacle for refuse in the centre—an arrangement which appears as if it had been expressly calculated to keep health low and mortality high. In Leeds, a similar style of building obtains, with a similar train of circumstances—'no effective drainage, inspection, or system of paving or cleansing.' The greater part of this town was described in 1839 as 'in a most filthy condition, demanding an immediate remedy.' It was mentioned, that in a certain dirty yard there was a house which for many years had been the seat of disease of a very malignant character: three years ago, the attention of the commissioners of police was directed to the extremely imperfect drainage of the surface-water: at that time, a better escape for the refuse-water was provided; and since that period, says the reporter, 'I believe *we have not had a single case of fever from that particular locality.*'

Narrow alleys and close courts, with wet filth constantly exhaling within them, and containing a densely huddled and extremely poor population, exist in Edinburgh, where, however, an exposure to high winds makes the evil less pestilential. In Glasgow, a comparatively level city, the same peculiarity exists to perhaps a greater extent than in any other British city. This, added to the miserably insufficient succour extended to the poor, and the influx of migratory Irish, renders Glasgow one of the unhealthiest cities in the empire.

FOOD—BEVERAGES.

IN the preceding sheet, we have shewn that man is destined to subsist on a mixed diet—that is, partly on vegetable and partly on animal food; and we shall now proceed to describe the specific characters of the more common alimentary substances, in as far as these have been determined by science and experience. In so doing, we shall consider their natural history and production, their chemical composition, their relative alimentary value, and the like, leaving their culinary preparation for the subject of a separate treatise. Before doing so, however, it will be necessary to establish a clear conception of the functions which food has to perform in the animal economy.

The body of man, like that of all animals, is composed of organic and inorganic substances: the former being present as fat, albumen, &c.; and the latter as various mineral salts and water. In general terms, it has been shewn by chemical analysis that the human body contains in 100 parts:

Organic Substances	Albuminous	20·7	= 23·2
	Fatty	2·5	
Inorganic Substances	Salts	9·2	= 76·8
	Water	67·6	
			100·0

During life, these constituents are incessantly undergoing change. Every thought of the mind, every action of the body, every manifestation of vitality, whatever be its nature, is accompanied by an alteration of tissue; and it is one of the functions of the food to supply the tissues with material wherewith to replace the losses which are thus sustained. This, however, does not represent the only important function of the food. For the continuance of life, it is necessary that a certain temperature should be maintained. While, to some extent, this is done by the heat produced during the chemical changes in formed tissue above alluded to, those changes do not of themselves generate a sufficient amount of heat, and the deficiency is made up by chemical transformations, resulting in the production of heat, taking place in a portion of the food which has not been formed into the tissues of the body. A further most important function of food is the production of those varieties of force or active energy which manifest themselves in muscular contraction, in secretion, and the like. As in the case of the production of animal heat, this force is partly the result of chemical changes in the formed tissues. Until recently, indeed, the variety of it known as muscular force was regarded, on the teaching of Liebig and others, as entirely resulting from oxidation in muscular tissue; but extended investigation has now rendered it certain that muscular action, in common with other forms of active energy in the body, results mainly from force generated by the food itself, and not by the tissues. No doubt, the tissues are concerned in the development of force; but in this respect their relation to the food seems analogous to that of the machinery in the steam-engine to its fuel, where the combustion of the fuel, and not the wear of the machinery, is the cause of the generation of power.

The substances removed from the body as excrementitious or waste material are made up of different quantities of inorganic and organic constituents; it is therefore necessary that these constituents should be present in the food within certain limits of quantity. The inorganic consist mainly of water and various mineral salts, and the organic of albumen—a compound containing nitrogen—and of fat, starch, and sugar—compounds destitute of nitrogen, but rich in carbon. Chemistry and physiology have shewn that, according to their composition, these various constituents of food have more or less distinct purposes to subserve in the living economy. Thus, the inorganic salts build up the skeleton or framework of bone; the nitrogenous portion of the organic mainly serves in forming or renewing the muscles and organs of the body; and the carbonaceous in supplying the energy that manifests itself in heat, and muscular and other forms of functional activity, and in constructing fatty and other tissues. But while these general statements indicate the leading purposes of the different constituents of food, it must be borne in mind that each of them takes a share in the main purposes of all the others. For instance, the organic aid the inorganic in forming bone, and the nitrogenous assist the carbonaceous in generating heat and muscular energy. As a matter of convenience, however, and having regard to their main functions, the leading organic constituents of food have been classified into the *nitrogenous*, or *plastic*, or *flesh-forming*, and the *carbonaceous*, or *heat-producing;* and the nutritive value of articles of food has been estimated from the relative quantities of carbon and nitrogen contained in them.

In attempting to arrive at definite conclusions regarding the quantity and kind of food required to maintain the body in a condition of health, we are greatly assisted by the accurate information that has been collected by many able and industrious writers in connection with the dietaries of troops, of large bodies of labourers, and of prisoners in jails. When these dietaries are contrasted with others that have proved to be insufficient—such as those of the Lancashire operatives during the cotton famine, or of the prisoners confined in Fort Sumter during the late American war—the minimum limit of a proper dietary can be defined with very considerable exactitude. Much valuable information of this kind has been collected by Mulder, Liebig, Payen, Christison, Playfair, Ed. Smith, and Parkes. From the results of these authorities, Dr Letheby has been enabled to state the *daily requirements of the body* in the following tabular form:

Daily Diets for	Nitrogenous Food.	Carbonaceous Food		Carbon.	Nitrogen.
	oz.	oz.		grs.	grs.
Idleness	2·67	19·61	=	3816	180
Ordinary Labour	4·56	29·24	=	5688	307
Active Labour	5·81	34·97	=	6823	391
					737

The first-mentioned of the dietaries is represented by 2 lbs. 2 oz. of bread, and the second by about 3½ lbs. The table shews that the relation of the nitrogenous to the carbonaceous constituents of the food should be about 1 to 6 or 6½. The dietary of women employed as indoor operatives should be one-tenth less than that of men. Children, until ten years of age, should be fed chiefly on milk and farinaceous substances; from ten to fourteen, they require about half as much food as women; and at fourteen, about the same quantity as women. Until their full growth has been reached, young men employed in active labour require more food than adults of the same sex.

The following table, also constructed by Dr Letheby, exhibits the relative quantities of carbon and nitrogen in a number of substances commonly used as food. The actual quantity of carbon present in the fatty substances mentioned has been purposely overstated. Unlike other hydrocarbons, fat contains hydrogen that is available as food; and when the value of this hydrogen is added to that of the carbon, the food-value of the latter element is increased about two and a half times. Accordingly, a correction to this extent is necessary whenever the carbon in fat is compared with that in starch or sugar.

	Grains per Pound. Carbon.	Grains per Pound. Nitrogen.		Grains per Pound. Carbon.	Grains per Pound. Nitrogen.
Split Peas	2698	248	New Milk	599	44
Indian Meal	3016	120	Skim Cheese	1947	483
Barley-meal	2563	68	Cheddar Cheese	3344	306
Seconds Flour	2700	116	Mutton	1900	189
Oatmeal	2831	136	Beef	1854	184
Baker's Bread	1975	88	Fat Pork	4113	106
Pearl-barley	2660	91	Dry Bacon	5987	95
Rice	2732	68	White Fish	871	195
Potatoes	769	22	Red Herrings	1435	217
Turnips	263	13	Suet	4710	—
Green Vegetables	420	14	Lard	4819	—
Carrots	508	14	Salt Butter	4585	—
Sugar	2955	—	Fresh Butter	6456	—
Buttermilk	387	44	Cocoa	3934	140
Skimmed Milk	438	43	Beer and Porter	274	1

With the assistance of such facts as are stated in this table, it is easy to construct a dietary suited to any condition of life. We have seen that a man engaged in ordinary labour requires daily 5688 grains of carbonaceous, and 307 grains of nitrogenous food. These quantities may be obtained from nearly any substance in which both carbon and nitrogen are present; but it is apparent that without judicious combinations an unnecessary excess of either is likely to be present.

FOOD.

The aliment of man consists of solid and liquid substances; hence such popular distinctions as 'meats and drinks,' 'food and beverages'—the one calculated to allay the cravings of hunger, and to afford the body substantial support; the other simply to allay the sense of thirst. Such distinctions, however, are more popularly convenient than scientifically correct—milk, for example, though liquid, being the sole support of the young mammal, and affording, moreover, nourishment to every portion of the fabric; while starch, though solid, yields comparatively little that can administer to the growth of the living tissues. Adopting, however, the common distinction of 'food and beverages,' as in some measure convenient, we shall treat the former under the three heads—*vegetable*, *animal*, and *mineral*—remarking that it is chiefly the vegetable and animal kingdoms (and especially the vegetable) from which man derives the greater portion of his solid sustenance. In the dietary of tropical countries, the vegetable element generally prevails over the animal; in temperate regions, the proportion is more equable; while in the colder latitudes, the flesh, and especially the fat, of animals may be said to be the staple of existence.

VEGETABLE FOOD.

Vegetable food, wherever employed, is consumed partly in a green and succulent state, either cooked or uncooked; partly in a ripe condition—as fruits, nuts, and the like; and partly when dried and artificially prepared—as the various bread-corns. In whatever condition or form vegetable substances may be used, they consist essentially of the same elements—carbon, hydrogen, oxygen, and nitrogen, with a small proportion of sulphur, phosphorus, and earthy salts. These are usually termed *ultimate* elements, from which the living vegetable elaborates certain *proximate* principles for the construction of its own peculiar fabric. These principles are—starch or fecula, gluten, vegetable albumen, sugar or the saccharine principle, fat, gum or mucilage, lignin or woody fibre, vegetable jelly or pectin, fixed and volatile oils, wax, resin, balsams, gum-resins, camphor, tannin, and colouring-matter. Of these, the most abundant are starch, gluten, albumen, sugar, and gum: these constitute the principal ingredients in all esculent vegetables; and it may be remarked, that starch and gluten are the most important as regards quantity—starch yielding carbon, and gluten, nitrogen. It may also be observed, that some of these proximate principles are convertible, or nearly allied: thus, starch can be converted into sugar by the process of fermentation, both outside and within a living organism; and albumen hardly differs from gluten.

One of the most abundant sources of vegetable food is the cereals, or bread-corns—wheat, rye, barley, oats, millet, and maize—all of which belong to the natural order *Graminaceæ*, or grain-bearing plants. All of these grow in a similar manner; all yield starch, gluten, and a certain amount of phosphates; and all have been cultivated and improved by the inhabitants of different countries from time immemorial. They are commonly spoken of as *farinaceous* foods; their *nitrogenous* elements being albumen, fibrin or gluten, and casein; and their *carbonaceous* elements, starch (principally), sugar, oil, and gum.

Wheat (*Triticum*) justly stands at the head of the cereals. Numerous varieties are recognised; but the principal are white and red wheat, the former being larger in the grain, and yielding a whiter and finer flour than the latter. It is now grown largely in all civilised countries, and forms a principal portion of human food. The grain, freed from its bran or husk, is usually ground to a fine *flour*, and in this state is used in the manufacture of bread, pastry, macaroni, vermicelli, semolina, and other preparations. It consists, as already stated, of starch, gluten, sugar, fat, gum, certain salts, and water; and these ingredients are found to vary, not only with the soil in which the corn is grown, but according to

the climate or latitude—that of Southern Europe yielding from two to six per cent. more gluten than that grown in the north. It is for this reason that Italian flour is so well fitted for the manufacture of macaroni; and that bakers often prefer a mixture of wheats in the composition of their loaves. The following are given as analyses of different wheats and wheat-flours:

	French Wheat.	Odessa Hard Wheat.	Odessa Soft Wheat.	First Flour.	Second Flour.
Starch.........	71·49	56·50	62·00	71·2	67·78
Gluten.........	10·96	14·55	12·00	10·3	9·02
Sugar.........	4·72	8·48	7·56	4·8	4·80
Gum.........	3·32	4·90	5·80	3·6	4·60
Bran.........	—	2·30	1·20	—	2·00
Water.........	10·00	12·00	10·00	8·0	12·00

Bread is the most important article of consumption prepared from the flour of wheat, and may be fermented or unfermented.

1. Common *fermented* or *loaf-bread* consists of wheat-flour, salt, water, and either yeast or leaven (old dough already in a state of fermentation). To these, bakers occasionally add potatoes and alum—the former to assist the process of fermentation, and render the bread lighter; the latter, to augment its whiteness and firmness. As to the addition of potatoes, there can be no objection beyond the substitution of an article containing an insufficiency of nitrogenous matter; but as to alum, it is highly objectionable, and its use by bakers is accordingly prohibited by law. The rationale of the fermenting process is this: 'The yeast or leaven causes the flour to undergo the vinous fermentation, by which carbonic acid and alcohol are formed. The carbonic acid is prevented from escaping by the tenacity of the dough, which, becoming distended with gas, swells up, and acquires a vesicular structure, forming a kind of spongy mass. In this way, therefore, are produced the vesicles or eyes, which give to ordinary loaf-bread its well-known lightness and elasticity. If the vinous fermentation be not checked in due time by *baking*, the dough becomes sour; and for this purpose, the mass, after being formed into loaves, is exposed in an oven to an elevated temperature, which puts a stop to the fermentation, expands the carbonic acid, expels the alcohol formed, and drives off all the water capable of being removed by the degree of heat employed. On weighing bread taken from the oven, it is found to be twenty-eight or thirty per cent. heavier than the flour used in its preparation.' From pretty accurate experiments, it has been found that the proportion of nitrogenous to carbonaceous matters in loaf-bread is as 1 to 7; in milk, the natural food of all young mammalia, the proportion is as 1 to 3·8.

2. *Unfermented* or *unleavened bread* is prepared in two forms—either heavy and compact, or light and spongy. The former condition is that in which all the varieties of biscuits appear—the main ingredient in these being flour worked into dough with hot or cold water. The other form of unfermented bread is that in which, by the use of effervescing compounds, it is rendered light and spongy, and made to resemble ordinary loaf-bread. Numerous receipts have been given, and several patents taken out, for the manufacture of this species of bread, but all of them may be readily comprehended from a description of the original method. It is well understood, that if we take hydrochloric acid and carbonate of soda, and mingle them in due proportions, an effervescence will take place, carbonic acid is disengaged, and common salt (chloride of sodium) is formed. Now, if we take the carbonate of soda and hydrochloric acid, and knead them as rapidly as possible with dough, an internal action will go on, the carbonic acid gas will raise the mass, the salt formed will season it, and, if properly baked, a light, sweet, and nutritious bread will be the result. The same result is attained by generating the carbonic acid gas in a separate apparatus, and then passing it, under pressure, into the dough, previously mixed with the requisite amount of salt. Such is the rationale of all the unfermented breads now so largely in vogue; though, of course, various bakers have adopted special modifications in the details of the process.

As to the merits of fermented and unfermented bread, the latter has the advantage in point of economy, there being no loss of nutritive principle through the destructive process of fermentation. The result of experiments upon the bread produced by the action of hydrochloric acid upon carbonate of soda, has been that in a sack of flour there was a difference in favour of the unfermented bread of about seven loaves.

Among unfermented preparations from wheat-flour may be classed a large variety of *cakes*, *pastry*, and *pudding*. The Italian preparations, *macaroni*, *vermicelli*, and *Cagliari paste*, consist of the finest wheat-flour. The first two have their well-known forms given to them by forcing the tenacious paste through a number of holes in a metallic plate; the last is pressed into the form of stars, rings, Maltese crosses, and the like. *Semolina*, *manna-croup*, &c. are granular preparations of the finest wheat deprived of bran. They possess, of course, all the nutritious properties of wheat, and are very agreeable, light, and well fitted for children and invalids. The same remark applies to the so-called *farinaceous foods* of the druggist, which are either wheat, pea, or lentil flour subjected to some heating process which bursts the starch granules, or admixtures of one or other of these with that of barley or oats.

Barley (*Hordeum*), of which there are several varieties cultivated in the British Islands, is one of the cereals found all over the temperate regions of the northern hemisphere—some of the varieties coming to profitable maturity even within the limits of the polar circle. As a staple of human food in northern countries, it is used in various forms: thus, freed from their husks by milling, the grains form *pot-barley*, used for making broth; still more thoroughly freed from husky matter, and rounded and polished in the mill, they constitute *pearl-barley*, used also in broth, and sometimes boiled in water and eaten as rice with milk; the common pot-barley, ground to flour, forms the *barley-meal* of the Scotch; and from pearl-barley similarly treated is obtained the *patent barley* of the shops. In any of these forms, barley forms a wholesome and nutritious food.

In 100 parts of Norfolk barley, Sir Humphry Davy found 79 starch, 6 gluten, 7 saccharine matter, and 8 husk. Proust, Vauquelin, and others have subjected this grain to analysis with very nearly

the same results; and Dr Thomson adds that the gluten of barley is partially soluble in cold water, as is shewn in the steeping of the grain for malting; but it coagulates at 120° or 130°, and falls down in gray-coloured flocks. In consequence of the small quantity of gluten it contains, barley is incapable of undergoing the panary fermentation, so as to form a light spongy loaf like flour from wheat. The barley *bannocks* or *scones* of northern countries are formed by kneading the meal thoroughly with water and a little salt, flattening the dough into cakes rather thin than otherwise, and toasting the same either on a hot iron plate (in Scotland, the *girdle*) or before a clear brisk fire.

The Oat (*Avena*), of which there are also a number of varieties cultivated in Britain, is one of the hardiest of our cereals. It can be grown with advantage where neither wheat nor barley will ripen; and indeed thrives best under a cold climate like that of Scotland, if the soil on which it is planted be sufficiently dry. It cannot be cultivated in the south of Europe, and is altogether a staple for the inhabitants of high northern regions. The entire grain is largely used as food for horses; freed of the husk, it forms *groats* or *grits*, and these, when crushed, are termed *Embden groats*, and when ground to flour, *prepared groats*. In one or other of these forms, oats are pretty extensively used as human food; but more largely as *oatmeal*, which is prepared by grinding the kiln-dried groats to various degrees of fineness, according to taste. This meal is not so white as wheaten flour, and has a peculiar agreeable odour. In various districts of the country, it is used for making bread, porridge, puddings, and other preparations.

Four specimens of Scotch oats, on being carefully analysed, gave the following results:

		HOPETOUN OATS.			POTATO OATS.
		Northumberland.	Ayrshire.	Ayrshire.	Northumberland.
	Starch	65·24	64·80	64·79	65·60
	Sugar	4·51	2·58	2·09	0·80
	Gum	2·10	2·41	2·12	2·28
	Oil	5·44	6·97	6·41	7·38
Protein Compounds.	Avenin	15·76	16·26	17·72	16·29
	Albumen	0·46	1·29	1·76	2·17
	Gluten	2·47	1·46	1·33	1·45
	Epidermis	1·18	2·39	2·84	2·28
	Alkaline Salts and loss	2·84	1·84	0·94	1·75
		100·00	100·00	100·00	100·00

From these data it would appear that oats are superior in point of nutrition to wheat; and experience proves that they form a substantial nutritive article of diet, since many of the labouring classes in Scotland, in Lancashire, Derbyshire, Northumberland, and other parts of England and Wales, subsist chiefly upon bread, porridge, and other oaten preparations. Oaten food, according to Pereira, is apt to disagree with those having a tendency to dyspepsia: in other words, it is apt to become acid on the stomach, and oat-bread, in particular, to occasion heartburn. With good digestive organs, however, and a proper amount of vigorous exercise, no inconveniences of the kind are experienced. *Porridge* or *stirabout*, which is composed of oatmeal, water, and a little salt, when well boiled, is one of the best forms in which oaten food can be taken, and partaken of with milk, constitutes a capital breakfast. When boiling water is slowly poured upon oatmeal, and mixed with it by stirring, after the addition of a little salt, what is called *brose* is produced. This is eaten along with milk, butter, or dripping, and constitutes the staple dish of the agricultural labourers in many counties of Scotland. *Gruel* is a mild, nutritious, and, in most cases, an easily digested article of food. On account of the nitrogenous principle which it contains, it is, of course, more nourishing than the starchy preparations (arrow-root, sago, tapioca, &c.) frequently employed in the sick-chamber. It may be prepared either from oatmeal or ground groats (Robinson's, for example), and may be sweetened with sugar, acidulated with lemon-juice, or spiced. Butter should never be added in the case of the dyspeptic, or where the stomach is tender. *Oaten-cake*, unless made with scalding water, and well fired, is apt to be heavy and heating.

Rye (*Secale cereale*), though cultivated to some extent on the light sandy soils of our country, can scarcely be considered as one of the staples of British consumption. The small amount grown, however, generally meets with a ready market, partly for distillation, and partly for the making of a light spongy bread, having a dark colour and a peculiar but rather agreeable flavour. Though little used with us, rye-bread, under the title of black-bread, is largely consumed by the peasantry of Sweden, Germany, Russia, and other northern countries, and has proved itself a very nutritive and strength-producing article of diet. The relation of the nitrogenous to the carbonaceous ingredients in rye-meal being as 1 to 9·8, it is less nutritious than wheat flour.

Rice—the *Oryza sativa* of botanists—is a plant of Asiatic origin, but is now extensively cultivated, not only in China, India, and other eastern countries, but in the West Indies and the southern states of America, as well as in the rich alluvial lands of Lombardy, and in the province of Valencia in Spain. 'It is the grand material of food,' says Marsden, 'on which a hundred millions of the inhabitants of the earth subsist; and, although chiefly confined by nature to the regions included between and bordering on the tropics, its cultivation is probably more extensive than that of wheat, which the Europeans are wont to consider as the universal staff of life.' Requiring a warm climate, it cannot be grown in Britain; but we import it largely—the Carolina and Patna rice being the most esteemed in the market. It is brought chiefly in the shelled or cleaned state; though attempts have been made to import the *paddy*—that is, rice in the husk—with a view to obtaining the grains in a fresher condition.

Rice consists chiefly of farina or starch, 100 pounds from Carolina yielding, according to Braconnot, not less than 85 starch, 5 fibrous matter, 4 glutinous matter, and 5 water, the remainder being sugar, gum, and phosphate of lime. It is therefore evidently much less nutritious than any of the preceding cereals, though it is light and wholesome, and altogether a valuable food when taken along with milk or some corrective condiment. It is prepared as an article of food in various ways, either whole or ground. It may be used like barley in broth, boiled and eaten with milk, boiled and dried as a substitute for potatoes, as an

accompaniment to curried dishes, or baked in puddings, which is perhaps the best mode of using it.

Maize or *Indian Corn* is the produce of the *Zea mays* of Linnæus—a cereal found native in America, but now largely cultivated, not only in the New World, but in several of the warmer regions of the Old. As an article of human subsistence, it is extensively used in the countries where it is grown; but did not, till the failure of the potato-crop in 1847, meet with much attention in Britain. In America, the tender young ears, in their milky state, are roasted and eaten with butter and salt as a delicacy, or boiled with meat. When green, they are also pickled as gherkins (young cucumbers); and dried, they keep all the year. When the grains are ripe, the skin is taken off, and the farinaceous part is boiled whole, or ground into meal, and made into cakes, puddings, &c. It is this meal which is chiefly known in Britain, and of which a variety of puddings, cakes, and loaves have been recommended.

Being extremely productive, maize can be cheaply produced, hence its great importance as an article of diet in America, Mexico, Natal, Italy, Spain, the south of France, and the Danubian Principalities. Its cultivation is not, however, restricted to these countries, but it is also extensively pursued in Turkey, Egypt, India, China, and the islands of the Indian Archipelago. The meal, called *hominy* or *cominy*, contains in 100 parts:

Starch.	Nitrogenous Substances.	Sugar.	Fat.	Salts.	Water.
64·7	11·0	0·4	8·1	1·7	14

It is therefore very nutritious. We find that those who live chiefly upon maize are robust, healthy, and fond of it as an article of diet. Its flavour is, however, somewhat rough and harsh, and hence it is chiefly preferred by those who have early been trained to its use. The substance known as *oswego*, *maizena*, or *corn-flour* is prepared by treating maize with a weak solution of caustic soda, in order to deprive it of gluten and of its harsh taste, and then drying the product.

Peas and *Beans*, which belong to the leguminous order of plants, are consumed partly in a green state, and partly when ripe and dried. It is the latter state with which we have at present to do; and it may be stated generally that their meal or farina is now but little used as an article of human food. Peas, split or whole, are used in the preparation of pea-soup; the meal, either pure or mixed, is still employed in some districts in the making of cakes; and, very finely ground and bolted, it is used as a supper-diet, under the name of *Glasgow brose-meal*. With regard to the amount of nitrogenous or nutritive matter which pulse and lentils contain, it is beyond what is found in any of the cereals. The nutritive effect, however, does not agree with this theoretical conclusion, partly from their deficiency in other wholesome constituents, and partly from the difficulty with which they are digested.

Sago—Tapioca—Arrow-root.—Of a considerable number of foreign starchy products, these are the most extensively used, and best known in Britain. The first is the produce of the sago-palm (*Sagus rumphii*), a native of the East Indies and Indian Archipelago. 'The part which affords the sago is the pith; and to procure this, the body of the tree, when it is full grown, is sawn into pieces, and the raw sago cut out and put into a trough with water, in which it is well stirred, to separate the flour from the woody fibre. This is now suffered to rest, and the flour subsides to the bottom. The water is then poured off, and the meal laid upon wicker-frames to dry. To form it into the round grains in which it is imported, the sago when moist is passed through a cullender, and rubbed into little balls, like shot, and then thoroughly dried. The sago-tree requires to be seven years old before being fit for felling; and a full-grown specimen will yield about 600 pounds of sago. The best sago is of a slightly pinkish hue, and readily dissolves to a jelly in hot water. Several other trees besides that above mentioned yield sago, but neither so abundantly nor of so excellent a quality.' The sago of commerce is imported either as sago-meal, pearl-sago, or common brown sago, which states have reference more to its form than composition. In all, the main constituent is starch, which, being light and easily digestible, renders sago an eligible substance for the dyspeptic and invalid.

Tapioca is obtained from the tuberous root of the *Janipha manihot* by grating and washing. It is usually met with in small irregular lumps, a form it has acquired by being dried on hot plates. The heat breaks the starch globules, and renders them partially soluble in cold water. In boiling water, tapioca becomes a transparent and viscous jelly. 'In its nutritive qualities,' says Pereira, 'it agrees with sago, than which it is much purer, being free from colouring-matter. It also yields a more consistent jelly than some other kinds of starch. It is principally employed as an agreeable light nourishment for invalids, as well as for children.'

The pure white starchy powder known as arrow-root is obtained from the tubers of the West Indian plant, *Maranta arundinacea*. It makes a tolerably strong jelly, stronger than that of wheat-starch, and is free from colouring-matter and also from any unpleasant taste or odour. It is used in the preparation of either puddings or gruel, like sago and tapioca. 'The best arrow-root we have,' says Webster, 'is from Antigua, Jamaica, and Bermuda; but a great deal of what is sold in London is adulterated with potato-starch, which, though a substance not very different, has not precisely the same properties. Arrow-root, like every kind of starch, boils to a jelly; but it differs from potato-starch in this respect, that the jelly formed from arrow-root will remain firm for three or four days without turning thin or sour, whereas the jelly from potato-flour, in the course of ten or twelve hours, becomes thin as milk and acescent; hence it is not so well calculated for food, and particularly infants'.' The proper value of all these substances, however, can be best appreciated by bearing in mind that they contain but a small portion of gluten in proportion to the starch. As food for the young, they are by far too largely employed; and the best American wheat-flour, good Scotch oatmeal, and barley-meal, may all be employed with advantage at different times, by way of variety, and repeated according to their agreement with the child's organs of digestion. The digestion of all these forms of food containing starch is greatly promoted by long boiling either with water or milk, as this process is just so much saved to the intestinal organs. It is thus obvious that we have a

great variety of food fitted for children, of which we know the composition, and that we should prefer it to any species of compounded stuff of the constitution of which we are ignorant.

The Potato (*Solanum tuberosum*) is one of our most abundant amylaceous or starchy vegetables, and next to the cereals, is one of the most common articles of human food. Originally discovered in South America, it is now introduced into almost every quarter of the globe, where it seems to thrive, and to break into innumerable varieties, differing in shape, size, colour, flavour, and quality. Without noticing minutely the peculiarities of the numerous varieties, we may remark that those of middling size, and which become white, mealy, and void of any especial flavour when boiled, are in general the most esteemed, as they are the most wholesome and nutritious. As they are an easily raised crop, producing twice as much bulk of food from the same extent of land as wheat, potatoes are very largely grown in the British Islands. Like all the *Solanaceæ*, or Nightshade family, the potato contains a poisonous principle (solaninia); but this is wholly destroyed by cooking. Citric and tartaric acids are also said to be present in various parts of the growing plant, and to these are likely to be ascribed the reputed antiscorbutic properties of the tuber. According to Johnston's *Chemistry of Common Life*, the potato contains 75 per cent. of water, and 25 of dry food. Of 100 parts of this dry food, again, 92 parts are starch and 8 parts are gluten, or a corresponding principle. Potato-meal is thus remarkably similar to rice-meal. No doubt can be entertained of the wholesome nature of the potato, when we consider the numerous hardy peasantry of Ireland, many of whom subsist almost entirely upon this useful vegetable. It must not, however, be imagined that potatoes contain the same nutritive powers as bread, weight for weight. It has been estimated, as the result of experiments made by Percy and Vauquelin, that one pound of good bread is equal to two and a half or three pounds of potatoes, and that seventy-five pounds of bread and thirty of meat are equal to three hundred pounds of potatoes.

In Britain, potatoes are generally brought to table boiled plain; but in France they are cooked in a great variety of ways, and furnish very agreeable dishes. Dr Letheby states that potatoes are best boiled in their skins, because the waste is then only 3 per cent., or half an ounce to the pound; whereas if they are peeled first, it is not less than 14 per cent., or from two to three ounces in the pound. The new or immature potato is much less easily digested than the fully ripened tuber, and should certainly be forbidden to the majority of dyspeptics. As already stated, potatoes are used in the manufacture of loaf-bread; and *potato-starch*, which is nothing more than dry starch-powder, is used, not only in fine bread and pastry, but as a substitute and adulterant of arrow-root.

The *Cabbage tribe* (*Brassica*)—which includes the common white and red cabbages, the savoy, greens, cauliflower, broccoli, &c.—is pretty extensively cultivated in Britain (see KITCHEN-GARDEN) for the purposes of human food. The parts used are the leaves which *heart* or gather together; and in the case of the cauliflower and broccoli, it is the young and compact flowering heads. As they contain upwards of 90 per cent. water, their nutritive value is not great; but they are valuable as antiscorbutics, and as agreeable substances with which to dilute rich food and increase the relish of insipid dishes.

The Turnip (*Brassica rapa*), which belongs to the same family, is perhaps still more largely consumed. The varieties best adapted for human food are the Swedish, yellow, and Dutch, all of which contain a considerable quantity of sugar and mucilage, with but little gluten. A hundred parts of turnip-bulb yielded Boussingault 92·5 water, and 7·5 solid matter; and this, when dried, only 1·7 of nitrogen—being but a third of the amount found in dried cabbage. Turnip-tops, or the young leaves gathered in spring, are occasionally used in England as greens.

The Carrot and *Parsnip* are two well-known umbelliferous roots, possessing highly nutritive properties, if chemical composition is to be taken as the test of alimentary value. They contain vegetable fibrin, albumen, sugar, and a volatile oil; 1000 parts yielding 95 sugar and 3 starch, or about six times the amount of sugar found in potatoes. They are valuable culinary vegetables in soups and stews. The fibrous matter they contain renders them somewhat difficult of digestion if not well boiled—a matter admitting of very easy remedy.

Beet-root, though largely made use of on the continent, is chiefly employed in England as a garnish for salads and other dishes, and as pickle. According to the experiments of M. Achard, 14 pounds of beet yield 1 pound of sugar; hence the manufacture of sugar from this root, and also its value in a culinary point of view. During the potato-failures, various preparations of beet were recommended as food for the poor; and among others, *beet-bread*, from an admixture of finely rasped beet and wheaten flour, fermented and baked in the usual form.

Of the vast variety of garden vegetables used as salads, pickles, garnishes, and so forth, none are consumed in such abundance as to entitle them to especial notice. Many of them are no doubt useful, others are useless, and not a few positively hurtful, though fashion and caprice may give them a place on our tables. Some notice of the more prominent—as lettuce, radish, spinach, celery, asparagus, artichoke, parsley, cress, onion, and the like—will be found under KITCHEN-GARDEN and COOKERY.

Preserved vegetables may be used with advantage, but chiefly when fresh vegetables cannot be obtained. The natural qualities of the vegetables appear to be best retained when they are inclosed, without being dried, in tin cases from which air has been excluded by heat. This method is successfully applied to potatoes, carrots, onions, &c. Fruits may be similarly preserved, either in tin cases or in bottles, a little water, syrup, brandy, or noyeau being added. Another method is to dry and then subject them to pressure. Potatoes, cabbages, cauliflowers, carrots, beans, &c. treated in this manner are reduced to about one-seventh of their original bulk, which they regain on being steeped in water. It has been found, also, that a useful method of preserving potatoes is to slice, dry, and then granulate them.

Sugar.—As already mentioned, sugar exists both in vegetable and animal substances, but

more abundantly in the former. In many of the products already noticed, the saccharine principle forms no unimportant item, though not in such proportion as to be considered characteristic. We now come to consider it as a distinct principle, and as an article of vast dietetic importance. Sugar, as a vegetable product, is found in considerable quantity in such dried fruits as the currant, raisin, fig, date, tamarind, and so forth; and these are now pretty largely consumed in Britain. Thus, figs yield about 60 per cent. of sugar; tamarinds, 12; prunes, 16; and dates, 35; and there can be no doubt that these, as well as many of our ripe fleshy fruits, owe their chief alimentary value to its presence. It is, however, as a separate and prepared article that we have now to do with it—as a substance obtained by art from the sugar-cane, the maple, the beet, the palm, and other plants yielding it in abundance. Though procured from the maple in America, from the beet on the continent, and from the palm in the East Indies, it is chiefly from the sugar-cane of the tropics that Britain obtains her supply, amounting annually to about 710,000 tons. When the canes, of which there are several varieties, have attained a certain height and age—about twelve or thirteen months—the cuticle having become smooth, dry, and brittle, they are cut, stripped of their leaves, and crushed between rollers, to express the juice, which is mixed with lime, to neutralise the free acid present, and render more liquid and separable the uncrystallisable portion, known as molasses or treacle. The juice is now heated in vacuum pans to the temperature of 130°, and separated from the scum, and again heated several times, and at length allowed to drain, for the separation of the *molasses* and the crystallisation of the sugar. The *raw* or *brown sugar* thus formed is again purified, by being acted upon by lime and bullock's blood: the one serving to neutralise the acidity of the liquids; the other, by the coagulation of the albumen, effecting the clarification and mechanical separation of any foreign insoluble matters. Reduced to a certain sirupy consistence, the sugar is poured into moulds, and agitated for a certain time, to prevent the formation of large crystals, and secure a compact mass of closely adherent, small, and glistening grains. This constitutes *loaf-sugar*, the quality of which depends greatly on the lowness of the temperature at which the boiling has been effected. When sugar thus refined has been again dissolved, and left to crystallise slowly at a somewhat elevated temperature, in boxes crossed with threads, to form centres of crystallisation, *sugar-candy* is formed; or if sugar so dissolved is made to cool more quickly, a transparent solid is obtained, known as *barley-sugar*. Sugar in one or other of these states constitutes the basis of almost all *confectionery*, as acidulated drops (sugar and tartaric acid), toffy, hardbake, comfits, lozenges, and the like. It forms also an excellent antiseptic, and for this purpose is used as a *sirup* for preserving fruits, roots, &c. as well as for the curing of meat and fishes.

In whatever form sugar or the saccharine principle may be made to appear in commerce or in diet, its ultimate composition, when pure, is carbon, oxygen, and hydrogen; or more simply, carbon and the elements of water. It contains no azotised principle, and thus its chief functions in the animal economy are to supply heat and form fat. It is generally supposed that sugar acts injuriously upon the teeth, but this is not a necessary effect of its consumption in large quantity; for Dr Wright informs us that 'no people on the earth have finer teeth than the natives of Jamaica.' When, however, saccharine substances are freely indulged in by those who live a more civilised, and probably therefore less healthy, life, gastric disorder is very likely to be produced, and, as a consequence, the quality of the secretions of the mouth is so modified that they act injuriously upon the teeth.

Honey, though, strictly speaking, obtained through the medium of the animal kingdom, may with little impropriety be considered in this place. Although elaborated by the bee, it is found ready-made, if we may so speak, in the flowering apparatus of many plants. It consists chiefly of grape-sugar, containing a greater or less amount of cane-sugar—the former being non-crystalline, while the latter is crystalline. Besides these two sugars, honey also contains a free acid matter not yet well understood, mucilage, sometimes a little wax, together with colouring and aromatic matter. These adjuncts differ, according to the kind of flowers on which the bees feed; and occasionally honey has been known to possess narcotic and poisonous properties. Its dietetic properties are thus spoken of: Like treacle, honey often acts as a laxative, and to a greater degree. But, like all other concentrated forms of saccharine matter, the digestibility of honey is only a comparative question; and, although honey may be much less apt to derange the functions of assimilation than cane-sugar or treacle, it is, nevertheless, by no means easily digested when the stomach is either weakened or otherwise less equal to its duties; and should always be used cautiously by the dyspeptic, if used at all by them. With some constitutions it by no means agrees, and has to be carefully avoided.

The fleshy fruits, as the apple, pear, plum, peach, and the like, though generally consumed during their seasons, cannot be regarded as a staple of food, though they are all more or less nutritious. About 80 parts in 100 are water, the rest consists of sugar and peculiar acids, associated with more or less gluten. According to Johnston, the perfectly dry gooseberry is about as nutritive as ordinary wheaten flour. Some, as the pear and apple, are employed in the manufacture of beverages; and as to their acid properties, these will be considered under the principles of MEDICINE.

ANIMAL FOOD.

Animal, like vegetable substances, are resolvable into ultimate and proximate principles. The *ultimate elements* of 100 parts ox-blood, for example, are—51·95 carbon, 7·17 hydrogen, 21·39 oxygen, 15·07 nitrogen, and 4·42 insoluble mineral matter. Again, 100 parts beef yield 52·59 carbon, 7·89 hydrogen, 19·00 oxygen, 15·22 nitrogen, and 3·30 insoluble ingredients. Comparing this with what has been said of vegetables, the vast preponderance of nitrogenous or plastic matter will be readily perceived. The *proximate principles* of animal food are—fibrin, or the fleshy fibre of meat when boiled to rags; gelatine, or animal

jelly; albumen, or white of eggs; oil and fat; osmazome, which gives to meat its peculiar flavour; creatine, a peculiar organic base; casein, such as the curd of milk or cheese, which is nearly allied to albumen; and, we may add, sugar, as in the case of milk. Of these principles are all animal bodies composed; always bearing in mind the large percentage of water which they contain (about 70 per cent. in lean or store cattle). These principles vary considerably in ultimate composition—thus, 100 parts of fibrin yield 53·36 carbon, 7·03 hydrogen, 19·68 oxygen, and 19·93 nitrogen; while albumen yields 50·00 carbon, 7·78 hydrogen, 26·67 oxygen, and only 15·55 nitrogen. Of course their relative values in point of nutrition depend upon composition and digestibility; and these must be ascertained with accuracy before any comparison can be instituted between fibrin and gelatine, gelatine and albumen, or albumen and casein.

Animal food is derived from the flesh, blood, viscera, bones, cartilages, ligaments, cellular tissue, milk, &c. It differs in nutritiousness, not only according to the kind or species of the animal, but according to the age, sex, food, and mode of life of the individual. Thus the flesh of young animals is more tender than that of old; that of the entire male adult, coarser and tougher than that of the female. Again, the flesh of store animals contains more water and less fat than that of fat animals, the process of feeding for the butcher tending, indeed, to substitute fat for water in the flesh of the animal. And, finally, just as the fibres of flesh are loose, tender, and minute, so are they the more easy of digestion. With these preliminary remarks, we shall proceed to notice in detail the leading articles of animal food made use of in Britain.

Beef, or the flesh of the full-grown ox, is largely consumed in Britain, perhaps more largely than a due regard to health and economy would allow. The quality of this article depends upon a variety of circumstances, such as the breed, sex, and age of the animal, and likewise the kind of food with which it has been supplied. 'Bull-beef,' says a leading authority on *cuisine*, 'has a strong disagreeable flavour, and is dry, tough, and difficult of solution. The flesh of the *ox* is more soluble; the fat is better mixed, the meat more sapid, and highly nourishing and digestible, if the animal is not too old. The flesh of the *cow* is sufficiently fit for nourishment, but is inferior to ox-beef; *heifer*-beef, or that of the young cow, is much esteemed; but that of an old fatted cow is bad. The beef of the larger varieties of the ox is inferior to that of the smaller breeds. . . . Grass-fed beef, or that produced from good farm-produce, is always better flavoured and more digestible than that reared from oil-cake, brewers' wash, and the like.' Beef is consumed both in a fresh and salted state; it is also pickled, smoked, and otherwise prepared. Salted, it is more difficult of digestion, while the salt, moreover, abstracts from it a considerable quantity of water holding valuable substances in solution. For various modes of pickling and preserving, as well as for an estimate of the comparative merits of boiling, broiling, and roasting, the reader is referred to the following article on the PREPARATION OF FOOD.

Extract of beef and *essence of beef* have, within recent years, become important articles of diet. The extract of beef prepared by Baron Liebig's process is a pale yellowish-brown substance of the consistence of honey, and having an acid reaction, and an agreeable meat-like aroma. The principal manufactory is at Fray Bentos, on the river Uruguay, in South America; and from this manufactory alone so much as 570,000 lbs. of the extract was produced during eight months of 1871. To produce this quantity, 122,075 head of cattle were slaughtered, and their estimated value was £330,000. The process essentially consists in boiling the previously minced meat in water, separating the fat from the solution thus obtained, and finally concentrating it by evaporation to the proper consistency. It is said that 34 lbs. of flesh (muscle), or 45 lbs. of meat including bone and sinew, are required for a pound of extract. According to Liebig, good extract should contain from 16 to 21 per cent. of water, from 56 to 60 per cent. of organic matter, and from 18 to 20 per cent. of mineral matter. The organic matter consists of creatine, creatinine, inosite, lactic acid, inosinic acid, &c.; and the greater part of the mineral matter of phosphate and chloride of potassium and chloride of sodium. It is altogether destitute of albumen, gelatine, or fat; and as these constitute the main nutritive ingredients of beef, extract of beef cannot in any proper sense be regarded as a concentrated form of beef, or as a dietetic substitute for it. Still, owing to the organic ingredients, and especially the creatine, creatinine, and inosite, which it contains, it is undoubtedly a valuable article of diet. These substances appear to have an action on the system analogous to that of the thein in tea, or the caffein in coffee. They diminish tissue-change and waste, and so only in a modified sense act as food, by diminishing the requirement of the body for nutritive material. On this account, beef-extract is of great value in many exhausting diseases; and forms an excellent article of diet when made into soup (a tea-spoonful—about 150 grains—to half a pint of water), and consumed along with vegetables or bread. Besides Liebig's extract, there are others which seem to be of equally good quality, and, like it, to deserve the confidence they have acquired. Several extracts in commerce, however, contain an undue proportion of water, and a deficient quantity of the peculiar organic constituents that render this preparation so valuable—the place of the latter being supplied by comparatively worthless gelatine. A less concentrated preparation constitutes the so-called *essence of beef*, of which that manufactured by the Messrs Gillon of Leith is now in extensive use. Sir Robert Christison has found that this essence does not contain albumen nor gelatine, and that its total solids amount to 6½ per cent. For making soup, it should be mixed with three times its bulk of water; and this soup is often preferred to that made of extract of beef, as it does not possess the peculiar and, to many people, unpleasant flavour of the latter.

Veal, or the flesh of the calf, is tender and nourishing, but not so easy of digestion as the prime parts of beef and mutton. Veal, particularly if it be young, contains much gelatine, as is the case with all young animals, and therefore yields a great deal of soluble matter when boiled long in water. This fact has led to the idea of its

being more nourishing than meat which is less soluble; but this does not follow, for the gastric juice acts differently from water, and can digest what that fluid cannot. Veal contains more nitrogenised matter than beef.

Besides beef and veal, strictly so called, the stomach, intestines, heart, lungs, certain glandular organs, bones, marrow, cartilage, &c. of the ox are variously made use of in the forms of tripe, sweetbread, haggis, &c. Tripe is easily digested and very nutritious, but non-satisfying; sweetbread is both easily digestible and nutritious, but its high price places it among luxuries rather than foods; and haggis, though containing much nutritious material, is difficult of digestion. Bone and cartilage constitute valuable stock for soups.

Mutton, or the flesh of the full-grown sheep, is also extensively consumed in Britain, and that almost wholly in a fresh state. Compared with beef, it is lighter, and more easily digested, owing very probably to the greater fineness of the fibres. The quality of mutton varies much in the different breeds. In the large long-haired sheep, it is coarse-grained, but disposed to be fat. In the smaller and short-wooled breed, the flesh is closest grained and highest flavoured; but the quality is probably most affected by the food on which the flocks are fed. Those which range over the mountainous districts of Wales and Scotland, or the chalk downs of England, and feed upon the wild herbage, possess a flavour very superior to those kept on rich pastures and marsh-land. Marsh-fed mutton often becomes extremely fat, but the meat has a rank taste. Turnips, hay, chaff, bran, corn, and other vegetables, as likewise oil-cake and grains, are employed for fattening sheep; but such mutton is never so good as that produced where the animals range at freedom. *Tup*-mutton, or the flesh of the ram, has a strong disagreeable flavour, and is usually tough; ewe-mutton, if under two years old, is good, but after that, it becomes hard and tough; wedder-mutton is the most esteemed. Mutton is in perfection at five years old, being then sapid, full-flavoured, and firm, without being tough; and the fat has become hard. Mutton under three years old is deficient in flavour, and is of a pale colour. *Lamb*, as the flesh of the young sheep is termed, is more tender and less exciting than mutton, but is not readily digested. It receives the name of lamb from the time it comes into season, in April or May, till the ensuing Christmas.

Preserved Beef and Mutton.—In many of our colonies, cattle and sheep are reared in numbers greatly in excess of the food requirements of the colonists, and a large proportion of this excess has hitherto been lost as food on account of the ignorance of efficient methods of preserving it, to admit of its importation into countries, such as Britain, where meat cannot be produced in sufficient quantity to supply the wants of the inhabitants. The conditions necessary for active putrefaction appear to be the presence of considerable moisture, the access of atmospheric air, and a temperature ranging from 40° to 200° Fahr.; and in the absence of any of these, putrefaction is prevented, or at least greatly impeded. Accordingly, numerous processes founded on the principle of excluding one or other of these conditions, have been devised, within recent times, for preserving meat. The result has been a great and rapidly increasing importation of meat, so that from Australia alone the quantity, irrespective of salted meat, was in 1871, 237,160 cwt. representing £513,186, as contrasted with 91 cwt. representing £321, in 1866; and to this falls to be added the enormous imports from New Zealand and South America. Without considering the special details of the processes of preservation, they may be described in general terms as tinning, curing, freezing, and subjection to chemical preparations. That by tinning is at present the one most successfully and extensively employed. This process consists in partially cooking meat from which all the bone and the greater part of the fat has been removed; and packing it in tin cans, which are then placed in a bath, having a temperature ranging from 200° to 300° Fahr., and finally hermetically sealed. If the sealing of the cans has been successfully accomplished, the contained meat is preserved from putrefaction for a practically indefinite period. This meat is now acknowledged by competent authorities to be perfectly wholesome, and to contain all the elements of nutrition in nearly the same proportion as ordinary British meat. In estimating the advantage to economy of using preserved meat, it is important to bear in mind that fresh butcher-meat is sold along with bone and an excess of fat, and that considerable loss occurs during cooking. Taking meat at the low retail rate of 10d. a pound, and allowing for bone and loss of weight by cooking (equal to nearly a half of the original weight), it is found that the price of the meat really presented as cooked food is about 1s. 6d. a pound. No doubt the bone can be afterwards used in the preparation of other dishes, but only a small proportion of its total weight is available as real nutriment. The fat likewise may be collected and economised as 'dripping,' but its market value is not equal to that of the meat from which it has been separated. The tinned meat being free from bone, already cooked, and sold at from 6d. to 8d. a pound, it is obvious that a great advantage to economy is gained by its use. As opposed to this advantage, however, there must be considered the slight impairment of its palatableness, and the comparative restriction of its culinary applications, which result from the more or less decided overcooking caused by the process of preparation. At the same time, the former of these is obvious to only a limited number of people, and in mitigation of the latter it may be urged that it does not prevent tinned meat from being employed in such various and favourite dishes as soups, haricot, stews, ragouts, and curries.

Pork, or the flesh of the pig, is invariably set down by writers on dietetics as difficult of digestion, but less so when pickled and cured than when fresh. Those who pursue the occupation of curing, cut the carcase in pieces, and pack it in kits formed to hold from 100 to 200 lbs. weight. A brine is then made by dissolving salt in water, until the mixture is so thick that an egg will swim in it. This is boiled, and poured upon the pork after it has cooled. Russian pork, always much esteemed, is steeped in a brine containing two pounds of loaf-sugar and three ounces of saltpetre to six pounds of salt, the whole being boiled in six gallons of water. After brine is added to pork in kits, the end of the receptacle is fixed in, and the article is usually sufficiently cured in a few days.

Hams are the hind-legs of the pig, cured by salting and smoking. They are generally in great request, and form an article of extensive consumption in Britain. *Bacon* is the whole side of a pig cured. It has been much vaunted by some as a remedy for indigestion, while by others a totally different opinion is entertained. Although it contains so large a proportion of fat as to render the second opinion plausible, experience shews that by the process of salting, this fat is rendered much more digestible than it otherwise would be.

The peculiarity of ham and bacon as nutritive substances depends on the large proportion of carbonaceous as compared with nitrogenous matter contained in them. When calculated as starch, the former bears the relation to the latter of 20 or 24 to 1. 'Hence it is,' to quote Dr Letheby, 'that they improve the value of substances which are rich in nitrogen, as eggs, veal, poultry, beans, and peas.'

Lard is that part of the fat of the pig which melts easily, and forms a fine, soft, white grease. It is extensively used, not only in household economy, but by the pastry-cook, apothecary, and perfumer. It should be, according to Martin Doyle, of *two* qualities. The finest and whitest is taken from the sides, and when well made, is far better than any salt butter for cookery, and, from the delicacy of its colour, is used by confectioners for the finest kinds of cake and pastry. The inferior lard is obtained from the intestines. The *blood* of the pig, we may also observe, furnishes a distinct article of food, being used in the preparation of the black-puddings of the shops.

Venison—Hare—Rabbit.—The flesh of the deer cannot be considered as an article of general consumption in the British Islands. A few years ago, the same remark was applicable to hares, rabbits, and other game. Now, however, the consumption of these animals is no longer chiefly confined to the upper and middle classes, for evidence given before a recent parliamentary committee has shewn that they are sold in almost incredible numbers to the working-classes of London, Birmingham, Manchester, Nottingham, and other large towns. Their flesh differs from that of the domestic animals in containing more nitrogenous matter, and less fat, and also in containing certain flavouring principles of a bitter or acid nature. From their constant motion and exercise, wild animals acquire a drier and harder flesh than that of the tame; and those parts which have the least motion—as the back of a hare, for example—are most juicy and palatable. From the same cause, the fluids of these animals are much more apt to putrefy than the fluids of the domestic kinds.

The term *venison*, though applicable to the flesh of all animals which are caught by way of hunting, is generally restricted to that of the deer kind—as the buck, the doe, the hart, and the hind. When well fed, killed at the right season, and properly dressed, venison forms a palatable as well as a wholesome and readily digested food. The flesh of *hares* was in high repute among the ancients, both in dietary and in medicine. The youngest and fattest are the best; and those bred on plains and mountains are preferable to those that live in moist places—the former feeding on aromatic herbs, which gives to their flesh a peculiar flavour. *Rabbits* are in more common use than hares; and their flesh contains less blood, and is therefore whiter than that of deer or hares. They are in prime season from the middle of October till the end of January.

Horse-flesh.—In presence of the great scarcity of animal food, it is unfortunate that prejudice should prevent the inhabitants of this country from adopting horse-flesh as an article of diet. Experience has distinctly shewn that the flesh of the horse is both wholesome and palatable. This has been known from a very early period of history. It is also attested by the common usage of the Tartars, Chinese, and other eastern nations; and by the increasing favour with which this description of meat is regarded by several European nations. Thus, while in 1853, a banquet, organised at Vienna for an experimental appreciation of horse-flesh, was prevented by the interference of a mob, in 1854, or one year subsequently, 32,000 pounds-weight of this food were sold to the populace within fifteen days. In times of unusual scarcity also it has been used with great acceptance. A conspicuous example of this was afforded during the late siege of Paris, where 30,000 horses were consumed within a period of four months. The writer can, from personal experience, recommend the flesh of the horse as a most agreeable and palatable food.

Poultry—Game-birds.—So far as experience goes, the flesh of all birds is edible, though that of some tribes is less palatable and wholesome than that of others. As an article of food, it is pretty largely consumed in this country—the domestic fowl, turkey, goose, duck, pigeon, partridge, grouse, and pheasant being the species which afford the chief supply. According to Brande, 100 parts of chicken-flesh yield 73 water, 20 albumen or fibrin, and 7 gelatine—that is, a total of 27 per cent. nutritive matter. Of a few birds, especially the woodcock and snipe, the legs are preferred to the breast. In the black-cock, the outer layer of the pectoral muscle is of a dark-brown colour, while the inner is white. A similar difference is observed in many other birds, and perhaps it is general in a slight degree. The muscular organs of birds differ from those of quadrupeds in their flesh never being marbled, or having fat mixed with the muscular fibres. This is so far advantageous, as the fat of most birds, the aquatic in particular, is extremely difficult of digestion and assimilation.

It is usual for writers on dietetics to classify the flesh of feathered animals according to its colour, or according to the leading habits of the birds as regards their food and mode of life. On the whole, it may be remarked that the younger and smaller the bird, the more delicate and tender the flesh; that the female is generally more tender and delicate than the male; that domestication renders birds more fleshy and tender; and that the more cleanly and carefully the animals are reared, the more wholesome and palatable their flesh becomes. It may also be added, as the result both of experience and experiment, that poultry is more easily digested when broiled; is somewhat less digestible when roasted; and is least easily digested when boiled. The less it is mixed and qualified by sauces, stuffings, &c. the better.

The eggs of birds—the hen, duck, goose, and turkey—are largely consumed in Britain, partly as a direct article of diet, and partly in puddings, pastry, and fancy-breads. It is scarcely necessary

to observe that the egg of the common fowl is that most extensively used, on account of its superior flavour and digestibility. Both the white and yolk consist chiefly of albumen, the former almost entirely so. Thus, 100 parts of white of egg yield about 80 water, 16 albumen, and 4 incoagulable mucilaginous matter; the yolk about 54 parts water, 18 albumen, and 28 a peculiar yellow oil. The solid matter of eggs consists of 14 parts of nitrogenous and 10½ of carbonaceous material. They are therefore deficient in carbon, and hence they are properly combined with bacon, with bread, with oil in salads, or with farinaceous substances in puddings.

With respect to the eligibility of eggs as an article of diet, much depends upon the mode of preparation; and, as a general rule, the lower the temperature employed in cooking them, and the shorter the duration of the cooking, the greater their digestibility. The yolk is more easily digested than the white; probably because the oil in the yolk prevents the albumen from coagulating in large masses, and thus allows the gastric juice to act more readily upon it. 'It is an important fact,' writes Dr Robertson, 'that either the white or the yolk of egg, if eaten raw, and therefore uncoagulated, is much more easily digested than when it has been previously boiled. The albumen is, of course, in this case, coagulated by the acid secretion of the stomach, as the first step to its digestion; but this coagulation is different from the coagulation by heat, and does not offer the same degree of resistance to the solvent powers of the stomach. The digestibility of egg is much influenced by its having been recently laid. Containing so much azotised matter, and the usual proportion of sulphur and phosphorus, egg soon undergoes the changes of decomposition; and probably to a considerable extent before these are to be detected by the sense of smell.' Eggs remain fresh for two or three days in summer, and for from three to six in winter. The shell being porous, the fluid contents gradually evaporate, and the shell becomes less full. To ascertain the age of eggs, dissolve about four ounces of table salt in forty ounces of water, and plunge the egg into it. If the egg is only one day old, it will fall to the bottom of the solution; if two days old, it will sink, but not to the bottom; if three days old, it will float near the top; and if five or more days old, it will remain at the surface and project more or less according to the age. When an egg is quite stale, the yellow falls to one end, and may be seen there on holding it before a light or the sun; and if the egg be shaken, a slight shock is felt, which is not felt if the egg be fresh.

Turtle.—Of the reptiles, which rank next in the descending scale of animated life, none can be regarded as a staple of food in this country. We leave the edible frog to our continental neighbours, and the turtle to the inhabitants of those regions of which it is a native. As a luxury, however, turtle is consumed by the wealthy, and is yearly becoming more common, as the facilities of steam-navigation bring it in much better condition, and much more abundantly. When cooked, the flesh of the green or edible turtle somewhat resembles that of chicken or veal; is pale, watery, soft, rich in gelatine, poor in fibrin, and contains little or no osmazome. It is said to be of easy digestion and nutritive; and by decoction, yields highly restorative soups. The eggs of several of the turtle family are eaten as a palatable article of food.

Fish—Crustacea and Shell-fish.—This division embraces a large amount of the food of our countrymen, and is steadily, though slowly, on the increase. Unlike the flesh of birds, that of fish is not always to be eaten with impunity. Many, indeed, are highly poisonous; and even the best are not always in season. They are said to be in season after full recovery from the operation of spawning, up to the time when the roe and milt are ripe, and about to be shed—and the nearer this point the better. Almost every portion of the common edible fishes is available as food; but the muscular, fleshy, or flaky part is that which forms the staple. It differs little in composition in the various kinds, being composed mainly of water, albumen, and gelatine. Thus, 100 parts of cod-flesh yield 79 water, 14 albumen or fibrin, and 7 gelatine; and that of the sole, 79 water, 15 albumen, and 6 gelatine. In many fishes, the flesh is mixed or covered with fat or oil, as in the salmon, herring, pilchard, &c.; but after the spawning season, this fat is greatly diminished. In the salmon, for instance, Sir Robert Christison finds, that while the fat amounts to 18·53 per cent. in 'clean' fish, it amounts to only 1·25 per cent. in kelts—the place of the lost fat in the latter being occupied by water. In other fish, as the cod, skate, &c. the fat seems concentrated in the liver, leaving the flesh nearly devoid of it. Fish-flesh contains, theoretically, a fair amount of nutritive matter; but this is greatly depreciated in many instances by its indigestibility. Ranged in their order of digestibility, fish, crustacea, and shell-fish may be thus classified: 1. White-fleshed fish; 2. Flat-fish; 3. Shell-fish; 4. Fresh-water fish; 5. Red-fleshed fish; and, lastly, the more oleaginous fish and the crustaceans, such as crabs and lobsters. From the quantity of water which the flesh of fish contains, it is less satisfying to the appetite than butcher-meat or poultry, at the same time that it is less substantial and nourishing. Besides the albumen, gelatine, mucus, and oil usually found in the substance of fishes, there are phosphates, chlorides, and iodides of lime, magnesia, soda, &c. which may give to it peculiar dietetic and medicinal properties.

For dietetic purposes, fishes have frequently to undergo some sort of preparation, varying according to the situation, the necessities, or the tastes of the consumers. 'When circumstances permit,' says Dr Fleming, 'they are in general used in a *fresh* state. . . . Where fish are to be procured only at certain seasons of the year, various methods have been devised to preserve them during the periods of scarcity. The simplest of these processes is to *dry* them in the sun. They are then used either raw or boiled, and not unfrequently, in some of the poorer districts of the north of Europe, they are ground into powder, to be afterwards formed into bread. But by far the most successful method of preserving fish, and the one in daily use, is by means of salt. For this purpose they are packed with salt in barrels as soon after being taken as possible. In this manner are herrings, pilchards, cod, and salmon, as well as many other kinds of esculent fish, preserved. The fish, in many instances, after having been salted in vessels constructed for the purpose,

are exposed to the air on a gravelly beach, or in a house, and dried. Cod, ling, and tusk so prepared, are termed in Scotland *salt-fish*. Salmon in this state is called *kipper;* and haddocks are usually denominated by the name of the place where they have been cured. After being steeped in salt, herrings are in many places hung up in houses made for the purpose, and dried with the smoke of wood. In this state they are sent to market under the name of *red-herrings*.' By the above processes of salting, drying, and smoking, the fibres of the flesh are hardened, and the digestibility of fish is to a corresponding extent impaired; though in some cases they may thereby be rendered more palatable and nutritious. The character of the fibres, indeed, will afford a trustworthy guide—other circumstances being equal—to the digestibility of the different kinds of fish. Thus the denser fibres of the skate render this fish less digestible than the turbot; and the same circumstance makes the halibut less digestible than the salmon. Prawns, shrimps, &c. like the lobster and crab, have hard, dense fibres, that are not easily dissolved by the gastric secretions. Muscles, cockles, &c. are less easily digested than oysters, and it is quite a mistaken notion that these are comparatively harmless in this respect. As to the nutritive properties of crustacea and shell-fish, they are in general greatly overrated. In the oyster, for example, 100 parts of the flesh yield about 88 water, and only 12 of solid or nutritive matter; while 100 parts of butcher-meat yield, on an average, from 25 to 28.

Milk — Preserved Milk — Butter — Cheese. — These are indirect animal products, all largely consumed in every country, whether savage or civilised. Milk, which is obtained only from the class Mammalia, and intended by nature for the nourishment of their young, is the basis of the whole—furnishing, according to certain changes, which it readily undergoes, cream, butter, curd, cheese, whey, and so forth. Intended by nature as the sole food of the young mammal, it necessarily contains all the elements of respiration and nutrition. Blood, flesh, bones, and every other tissue, are formed from its elements: it is, in fact, a perfect food—that is, perfect in its kind, up to a certain stage of animal development. Its proximate constituents are casein, butter, sugar of milk, various salts, and water; and these differ not only in various animals, as the following analyses will shew, but also according to the food, the age, and the period after parturition. Thus:

100 Parts of	Casein.	Butter.	Sugar.	Salts.	Water.
Cow's Milk yield......	4·48	3·13	4·77	0·60	87·02
Ass's "	1·82	0·11	6·08	0·34	91·65
Woman's "	1·52	3·55	6·50	0·45	87·98
Goat's "	4·02	3·32	5·28	0·58	86·80
Ewe's "	4·50	4·20	5·00	0·68	85·62

Such analyses, however, are to be regarded only as approximations, for the food, age, &c. must ever be taken into account. A cow fed on carrots, for example, yields a milk containing more casein and butter than when she is fed on beet-root. The salts consist chiefly of phosphates of lime, magnesia, soda, and iron. Milk as an article of diet for adults is obtained in Britain almost solely from the cow; goat and ewe milk being only occasionally used in the preparation of cheese; whilst that of the ass is partaken of by invalids.

When milk is mixed with about one-third of its weight of sugar, and evaporated in vacuo to the consistence of thin honey, the preparation known as *preserved* or *condensed milk* is obtained. This has recently become an important manufacture in Switzerland, Bavaria, England, and Ireland. It is preserved in tin cans, and remains perfectly fresh for many months, during even the hottest seasons of the year. When diluted with twice its bulk of water, it makes a good milk of ordinary strength, greatly superior in quality to the milk often supplied to the inhabitants of towns and cities, and admirably adapted for the nourishment of infants deprived of their ordinary food.

Referring the reader to the article DAIRY for the management and preparation of milk, cream, butter, cheese, and the like, we shall here merely advert to the respective dietetic peculiarities of these preparations. Cow's milk, when obtained from healthy, well-fed, and properly kept animals, is a very useful and valuable article of food, as well for adults as for children. Its principal drawback, according to Pereira, is the difficult digestibility of its fatty constituent, or butter—an objection, however, which can be got rid of by using it in the *skimmed* state. Under the name of *milk-diet*, it is extensively employed in conjunction with bread, oatmeal, rice, sago, potatoes, and other farinaceous substances, and forms in every case a readily assimilated and nutritive aliment. *Cream* consists of butter, curd, and serum or whey, and though less digestible than milk, properly so called, is not so liable to this objection as butter. Fresh *butter* is more easily digested than salt; and whether salted or fresh, preference is always to be given to that most recently prepared. *Whey* is chiefly composed of water and lactic acid, with a slight proportion of casein, butter, and sugar. It is therefore very slightly nutrient, but forms an excellent diluent in inflammatory complaints, and also gently promotes the secretions. *Butter-milk*, as containing the casein, the sugar, and the salts of milk, must possess nutritive properties. It is deserving of wider adoption, both as an article of diet, and as a cooling and agreeable beverage. *Curd* is less easily digested than cream; but more so than butter. It consists mainly of casein, and this from fresh milk yields 54·83 carbon, 7·15 hydrogen, 15·63 nitrogen, and 22·39 oxygen and sulphur. *Cheese*, or casein dried, and having probably undergone some chemical change during the process of 'ripening,' is generally very difficult of digestion. It usually contains a considerable proportion of the fatty part of the milk, and in some cases is made almost entirely from cream, as in the double Gloucester and Stilton cheeses. Cheese made from cow's milk is more easily digested than that from goat's milk; and the richer or more oleaginous the cheese, the more easily is it digested. Ripe cheese is preferable to that which is green or immature, and also to that which is partially decayed.

Animal fat, like the oil of vegetables, consists essentially of carbon, hydrogen, and oxygen. Containing about 80 per cent. of carbon, *heat-producing* is one of its main functions, and thus is explained the fact, why the inhabitants of cold climates can consume with impunity so much of this aliment. All fatty matters are digested with

difficulty, and are apt to irritate and derange the stomach and its functions. The fat of different animals, however, differs in point of digestibility; and, what is more curious still, differs also according to the part of the animal from which it is taken. The digestibility of fat is much affected by modes of cooking; it is also greatly modified by the action of vegetable acids and of common culinary salt.

MINERAL FOOD.

It has been already mentioned that man derives little of his food directly from the mineral world, and that the greater number of saline and earthy substances indispensable to healthy aliment are obtained indirectly from the vegetable and animal products used by him as food. In fact, the only substances obtained directly from the inorganic kingdom, and consumed in large quantities, are water and salt—two substances as necessary to existence as the air we breathe. The former, as has been seen, enters largely into the composition of every species of food; it acts as a solvent and diluent in all cases, and permeates everywhere the tissues to whose subsistence and growth it administers. The latter, though usually taken as a palatable condiment, is really essential to the maintenance of health and vitality, and accordingly appears as a constituent of the blood and the tissues elaborated therefrom.

Water, as consumed by man either as a beverage or as a constituent of his food, is generally in a fresh state; that is, contaminated as little as possible by foreign ingredients. The nature and constitution of water have been already detailed under the heads CHEMISTRY and SUPPLY OF WATER: all that is necessary to be here observed is, that the supply for dietetic uses should be freed from all mechanical impurities, and from all chemical impregnations, which may render it unpalatable, unsuitable for culinary purposes, or detrimental to the system of the consumer. Absolutely pure water is not found in nature, nor does it indeed seem to be required by the animal economy. It is only pure when distilled, and even if wholesome in this state, it is not palatable until it has reabsorbed more or less of the gaseous constituents separated from it by the process of distillation. The purest waters always contain some amount, however small, of common salt, lime, magnesia, iron, and other saline matters; as also organic matter. It is only when these foreign substances exist in large amount that water becomes objectionable.

Respecting the alimentary functions of water, Dr Pereira, after remarking that it is the natural drink of all adults, observes: 'It serves several important purposes in the animal economy: *Firstly*, It repairs the loss of the aqueous part of the blood, caused by evaporation and the action of the secreting and exhaling organs; *Secondly*, It is a solvent of various alimentary substances, and therefore assists the stomach in the act of digestion, though, if taken in very large quantities, it may have an opposite effect, by diluting the gastric juice; *Thirdly*, It is probably a nutritive agent—assisting in the formation of the solid parts of the body. It has not, indeed, been actually demonstrated that water is decomposed in the animal system; or, in other words, that it yields up its elements to assist in the formation of organised tissues; yet such an occurrence is by no means improbable. It appears from Liebig's observations, that the hydrogen of vegetable tissues is derived from water; and it is not probable that the higher orders of the organised kingdom should be deficient in a power possessed by the lower orders. Dr Prout appears to admit the existence of this power, but thinks that it is rarely exercised by animals. The water which constitutes an essential part of the blood and of the living tissues, assists in several ways in carrying on the vital processes. "In the blood," says Prout, "the solid organised particles are transported from one place to another; are arranged in the place desired; and are again finally removed and expelled from the body, chiefly by the agency of the water present." It is from water that the tissues derive their properties of extensibility and flexibility. *Lastly*, This fluid contributes to most of the transformations which occur within the body.'

Salt.—Referring the reader to our article on USEFUL MINERALS for an account of the modes of procuring and preparing this indispensable article, we shall here strictly confine our remarks to its dietetic or alimentary importance. This substance occurs in all vegetable and animal organisms, and hence a certain quantity is present in every article of food. In the human body, it constitutes one-half by weight of the total salines of the blood; but it is unequally distributed throughout the fluids and structures, very little being present in the bones and teeth, and so much as 13 parts in every 1000 in the tears. It is a remarkable fact that the proportion in the blood does not seem to vary, for even after large quantities have been taken, the excess which for a time occurs in the blood, is quickly got rid of by increased elimination; while the proportion in the blood cannot be diminished to any marked extent by giving food from which salt has been altogether removed. Salt has the property of increasing tissue-changes, as judged by the augmented excretion of urea and the elevation of temperature; under its influence, animals consume more food, and become stronger and more active; but they do not, to a corresponding extent, gain in weight, on account of the simultaneous increase of tissue-change, and therefore of tissue-waste, which occurs. In virtue of the chlorine it contains, salt renders the gastric juice more abundant and more acid, and in this way also it improves digestion. It appears to have a beneficial influence on various other secretions, and markedly upon that of the mammary glands, the quantity of milk secreted during lactation being increased, and its quality often improved. The necessity that a certain quantity should be supplied with the food, is shewn by the instinct of animals, the promptings of appetite, and the result of numerous observations in which the health has suffered from its deprivation. The amount of salt consumed by a full-grown person has been estimated at 16 lbs. a year, or about 5 oz. a week, or three-fourths of an ounce a day; but of course this estimate will vary exceedingly according to the tastes and habits of individuals.

All the varieties of salt, whether small-grained, like the *basket* or *table salt*, or in large crystals, like the *bay* and *fishery salts*, consist essentially of chloride of sodium, which is composed of 60 per

cent. chlorine and 40 sodium. The salt of commerce, however, is never found absolutely pure, being less or more contaminated with salts of lime and magnesia, as well as insoluble matter. Thus an average of foreign bay-salts yielded to analysis 3½ per cent. of such impurities; British salt from sea-water, upwards of 4 per cent.; and that from English rock-salt, somewhat more than 1½ per cent. The purer salt is, of course the more wholesome will it be as an article of diet, and the more effectual for the purposes of pickling and curing provisions.

BEVERAGES.

Writers on dietetics are in the habit of classifying drinks or beverages according to their sensible, chemical, or medicinal properties. Thus we have—1. Mucilaginous, farinaceous, or saccharine drinks; 2. Emulsive or milky drinks; 3. Animal broths, or drinks containing gelatine and osmazome; 4. Aromatic drinks; 5. Acidulous drinks; and, 6. Alcoholic and other intoxicating drinks. Water, however, is the only true natural beverage; it forms the basis of the whole of the above—the other constituents being merely solid or liquid substances mixed with or dissolved in it. Being reduced to a condition of minute subdivision, the alimentary action or effect of such of these substances as possess a dietetic value is much facilitated, and thus, in point of easy assimilation, beverages are immensely superior to solid food. We shall now briefly allude to the more abundant and familiar beverages.

1. The mucilaginous, farinaceous, and saccharine drinks are perhaps the simplest, next to water. They are merely solutions, infusions, or decoctions of substances already described, and are known by such terms as *gum-water*, *toast-water*, *sugar-water*, *barley-water*, *mucilage of rice*, and *gruel* from oats, sago, arrow-root, or tapioca. They are all very slightly nutritive; and are used chiefly in the sick-chamber as demulcents and diluents.

2. Emulsive or milky drinks are such as hold in suspension any oily or fatty substance in a finely divided state. *Animal milk* (already described) is at the head of this section.

3. Broths and soups, or drinks containing gelatine, creatine, creatinine, inosite, osmazome, &c. are usually prepared from beef, mutton, veal, and chicken. As in the case of extract of beef, their nutritive properties depend chiefly upon the creatine and allied principles contained in them, for no satisfactory evidence exists regarding the value of gelatine as a food. It is not unlikely, however, that this substance assists in forming the gelatinous tissues, and that it also, like albumen, generates force by its oxidation in the body. Meat of good quality yields to boiling water, creatine, creatinine, and similar principles, osmazome, gelatine, fatty matter, some salts and water; and to prepare a soup so that none of these may be dissipated and lost, is the chief point requiring attention. When pot vegetables, as turnips, carrots, onions, barley, &c. are used, of course these communicate new principles to the liquid—as mucilage, sugar, azotised products, volatile oil, and salts.

4. Of the aromatic drinks, tea, coffee, and chocolate are pre-eminently the most familiar. 'We shall never, certainly, be able to discover,' writes Baron Liebig, 'how men were led to the use of the hot infusion of the leaves of a certain shrub (tea), or of a decoction of certain roasted berries (coffee). Some cause there must be, which would explain how the practice has become a necessary of life to whole nations. But it is surely still more remarkable that the beneficial effects of both plants on the health must be ascribed to one and the same substance, the presence of which in two vegetables belonging to different natural families, and the produce of different quarters of the globe, could hardly have presented itself to the boldest imagination. Yet recent researches have shewn, in such a manner as to exclude all doubt, that *caffein*, the peculiar principle of coffee, and *thein*, that of tea, are in all respects identical.' The fact is certainly striking enough, and all the more so that cocoa or chocolate, maté or the tea of Paraguay, and guarana, the common beverage of the native tribes in the neighbourhood of the Amazon, also yield principles identical with thein and caffein.

Tea was presented, in 1664, as a rare and precious gift, to the queen of England, and now it forms an almost essential article of consumption in the poorest households of the kingdom. From a recent official account, it appears that in 1871, the enormous quantity of 123,401,889 lbs. or over 55,090 tons was used in this country, or about 3½ lbs. during the year by each individual. The greatest quantity is obtained from China, but ever-increasing supplies are derived from Assam and Cachar in Hindustan. The botanical source of tea is a plant named *Thea sinensis*, of which two varieties are distinguished, *T. viridis* and *T. Bohea*, from either of which green or black teas may be produced. Of the green teas, there may be mentioned, in their order of quality and expensiveness—Young Hyson, Gunpowder, Hyson, Imperial, and Twankay; and of the black teas, in the same order—Flowery Pekoe, Orange Pekoe, Pekoe, Souchong, and Congou. When analysed, they all yield chlorophyl or colouring-matter, wax, resin, gum, albumen, lignin, extractive matter, tannin, empyreumatic volatile oil, and thein. The important and valuable properties of tea seem to depend on the last two of these substances, although decided effects are likewise caused by the tannin. The volatile oil is not present in the fresh leaves, but is produced by decomposition of some of the natural ingredients during the heating to which tea is subjected in its manufacture. It has an exhilarating action, which manifests itself by producing, among other effects, wakefulness and increased mental activity. Thein is a nitrogenous proximate principle, having, when pure, the form of shining, colourless, crystalline needles. It is probably the most valuable constituent of tea, for it has the remarkable power of diminishing waste of tissue, and so economising food. Hence it is that, with a limited quantity of food, more work can be performed when tea is taken, than without it; and that, in old infirm persons, where the desire for tea is so strong, the waste and decay of the system are lessened. The tannin of tea closely resembles the astringent principle of oak-bark, gall-nuts, &c.; and it is doubtful if it confers any advantageous properties to this beverage. In preparing tea for use, an infusion should be made with boiling water; but the infusion should never be boiled, otherwise the

volatile oil will be dissipated, with corresponding loss of aroma, and, at the same time, astringent and bitter principles will be dissolved in too large quantity from the leaf. Tea is usually measured into the pot by the spoonful. Though no doubt convenient, this method is a very inaccurate one; for Dr Edward Smith has shewn that the weight of a spoonful varies greatly according to the kind of tea used—an average spoonful of flowery pekoe, for instance, weighing 62 grains, and one of congou 87 grains. Taken at the same time as a heavy meal of food, or such a meal as contains a large proportion of the day's alimentary supply, tea may prove to be too much of a diluent, and in some cases may rather retard the primary digestion, by precipitating the pepsine of the gastric juice. This, however, depends very much on the quantity and the strength of the infusion made use of. Green tea, although said to be used almost exclusively in some countries, is found to be unsuitable for exclusive use in this country. It often produces injurious effects, which may, to some extent, be ascribed to the deleterious colouring-matters with which it is frequently adulterated. Apart from this cause, however, green as well as black tea injures the health when taken in excessive quantity; dyspepsia, nervous irritability, and sleeplessness being among the more prominent symptoms induced.

The *Coffee* of commerce is the seed of a berry-bearing tree or shrub, *Caffea Arabica*, found originally in Abyssinia, but now extensively cultivated in Persia, Arabia, and other tropical countries. It is usually distinguished by the place of its growth—as Mocha, Jamaica, Mountain-Jamaica, Demerara, Ceylon. Raw coffee can be kept for any length of time without deterioration—indeed, the older the better; but on being roasted, it develops a fragrant and aromatic principle, which is extremely volatile. Roasted coffee should therefore be ground and used as speedily as possible. Coffee yields to analysis caffeic acid, tannic acid, caffein, wax, resin, fat, gum, albumen, lignin, extractive matter, and salts of lime, magnesia, and iron. By roasting, the quantity of water and caffein is lessened in the coffee-beans, and at the same time a new substance of an oily nature is produced, which is sometimes called caffeon. The action of coffee closely resembles that of tea. It has the power of retarding waste of tissue, of inciting and invigorating the mental functions, and of producing wakefulness. The first of these is mainly, if not solely, due to the caffein; the others are due to the caffeon, and possibly also in part to the caffein. Caffein, as has already been stated, seems identical in composition to thein. Caffeon is an empyreumatic substance resembling the empyreumatic oil of tea, and to it also may be referred the grateful aroma of this beverage. Independently of any differences in the relative proportions of these two important ingredients, coffee is more nutritious than tea; for when infusions of ordinary strength of the two are compared, it is found that a moderate-sized cup (5 oz.) of coffee contains about 44 grains of solids, while one of tea contains only 6·6 grains—the greater part of these solids being nutritious. The addition of milk to coffee adds much to its nutritiousness, diminishes in some degree its local effects on the stomach, and seldom makes its digestion more difficult. As to the addition of *chicory*—the root of the wild succory, or endive, dried and ground—it is thought by some to improve the flavour and appearance of coffee. At the same time, it does so only when added in small quantity; and it is quite unjustifiable to leave it to the cupidity of the seller to dilute a substance possessing valuable physiological properties with one that has no very appreciable action. The unrestricted addition of chicory is only too apt to lead to adulteration, quite as unfair to the consumer as that with dandelion root, roasted wheat, or other substances whose dietetic and market value is greatly inferior to that of coffee.

Cocoa is derived from the seeds or nuts of the chocolate-tree (*Theobroma cocoa*), a native of tropical regions. The seeds grow in pods, and are prepared for use by being roasted, deprived of their husks, and ground. Cocoa is either used in the form of the ground seeds, simply made into a decoction; or these are ground into a paste, mixed with cloves, cinnamon, vanilla, &c. forming *chocolate*. It contains theobromin, a principle undistinguishable from caffein, and it exerts the same influence on the system as tea and coffee. As an article of diet, cocoa is more nutritious than these substances, owing to the large proportion of fat (52 per cent.) contained in it. Hence, it is for many a somewhat heavy and indigestible beverage. The ground seeds are preferable to the paste or cakes, of whose composition, or, we should rather say, adulteration we are ignorant.

5. The acidulous beverages in common use are *lemonade*, *ginger-beer*, *soda-water*, *effervescing saline draughts*, *Seidlitz powders*, and the like. Their action being medicinal and corrective, rather than alimentary, their consideration properly belongs to a subsequent number. When prepared from the acid juices of fruits—as lemon, raspberry, apple, &c.—they form cooling, refreshing antiscorbutic drinks, and are well adapted for hot seasons and for febrile and inflammatory cases. When compounded of some alkali and acid, like the common effervescing draughts, they are also slightly aperient.

6. Beverages which are the products of fermentation are usually classed as *spirits*—brandy, gin, whisky, and rum; *wines*—port, sherry, claret, champagne, &c.; *liqueurs*—embracing all the sweet or home-made wines; and *malt liquors*—ale, porter, and beer.

Alcohol, or the leading principle in spirits, consists of carbon, hydrogen, and oxygen. As it is very inflammable, and produces heat and carbonic acid while burning, Liebig was led to maintain that it has an important alimentary function in elevating the temperature of the body. Recent experiments have rendered this view extremely doubtful, by shewing, among other results, that after alcohol is swallowed, a large proportion of it is eliminated from the body unchanged. It does not seem necessary, however, to discuss the relative probability of either of these views, because, although such a discussion is of great physiological importance, it does not possess an equally important bearing on the use of alcohol as a beverage. At the present time, the opinion, founded on numerous careful observations, appears to be generally accepted that alcohol, like tea, coffee, &c. has a decided influence in diminishing waste of tissue. It also is universally held to be a powerful mental stimulant, and, in certain

circumstances, to aid digestion. These actions render it valuable in the treatment of disease, in removing debility, and in supplementing an insufficient dietary. Its effects on the mental functions, however, probably account, in greatest part, for its extensive use, and confer upon it those seductive attractions that are so generally recognised. When taken in doses too small to cause decided intoxication, it brightens the intelligence, increases courage, elevates the spirits, excites the imagination, and produces a feeling of general self-satisfaction and complacency. In the presence of misery, therefore, it is not to be wondered at that refuge should be sought in an agent capable of producing forgetfulness of misery. Unfortunately, however, its use in such circumstances leads to craving and excessive indulgence; and hence follow the lamentable effects of such indulgence, which may be shortly described as physical deterioration with concomitant mental, moral, and social degradation. There does not seem to be any perfectly satisfactory reason for altogether interdicting the use of alcohol as a beverage on account of the pernicious effects that follow its excessive use. That recourse should be had to this extreme step is rather an admission that some degree of the moral degradation to be prevented already exists. No doubt, however, such degradation is widely spread in all ranks of society, though most prevalent in the lowest; and the task of removing it is greatly increased by the continuance of so potent a cause as excessive alcoholic indulgence. Without dwelling further on this subject, it must be borne in mind that great benefit is derived from the moderate use of alcohol in many conditions of the system. It is of value especially in old age, in general debility, in feeble digestion, and in dyspepsia accompanying a too rich or excessive dietary. When used in these conditions, careful attention should be given to the fact, that many of them may be removed without its aid, and that its use is attended with the danger of leading to the acquirement of habits of excessive indulgence. These observations are not intended to refer to the employment of alcohol as a therapeutic agent in the hands of qualified medical men.

Brandy, derived from the distillation of wine, and of the refuse of the wine-press, consists of alcohol, water, volatile oil, a minute quantity of acetic, œnanthic, and other ethers, and colouring-matter. It is distinguished from other ardent spirits by its cordial and stomachic properties. *Rum*, distilled from molasses and sugar-skimmings, possesses a peculiar aroma, due to the presence of butyric ether, and is very similar to brandy in its effects. *Gin*, obtained from corn-spirit, and flavoured with juniper, sweet flag, &c. is, owing to the oil of juniper it contains, more powerfully diuretic than either brandy or rum. *Whisky*, also a corn-spirit, agrees in most of its properties with gin, but is less apt to disorder digestion.

Wine is the general term applied to liquors prepared by the vinous fermentation of the juice of the grape. 'The peculiar qualities of the different kinds of wine depend on several circumstances; such as the variety and place of growth of the vine from which the wine is prepared; the time of year when the vintage is collected; the preparation of the grapes previously to their being trodden and pressed; and the various manipulations and processes adopted in their fermentation.' Though thus varying, and known by a thousand names, the general constituents of all wines are—water, alcohol, volatile oil, œnanthic, citric, malic, and other ethers; sugar, gum, tannin, tartrate and bitartrate of potash, acetic acid, extractive and colouring matters, and carbonic acid, in the effervescing varieties. The bouquet of wines is derived from the essential oils and ethers. The amount of alcohol they contain is exceedingly varied: in claret, for example, it seldom exceeds 7 or 10 per cent. by volume; while in ports and sherries it ranges from 15 to 25 per cent. As to the dietetic properties of wine, Dr Paris asserts 'that there exists no evidence to prove that the *temperate* use of good wine, when taken at *seasonable* hours, has ever proved injurious to *healthy* adults.' Dr Pereira is by no means disposed to question this assertion, qualified as it is; but maintains, on the other hand, that 'for healthy individuals, wine is an unnecessary article of diet. It may prove,' he continues, 'a valuable restorative when the powers of the body and mind have been enfeebled by fatigue; but, on the other hand, it cannot be denied that the most perfect health is compatible with total abstinence from wine; and that the habitual employment of it, especially by the indolent and sedentary, is calculated in many instances to prove injurious. Disorders of the digestive organs and of the brain, gout, gravel, and dropsy, are the maladies most likely to be induced or aggravated by the use of wine.' Wines differ greatly in their properties, according to the proportional amounts of their several ingredients. Besides those referred to, astringent, laxative, and nutrient properties are conferred upon them by the tannin, potash salts, sugar, and extractive matters which enter into their composition.

Malt liquor is the generic term for all fermented infusions of malt flavoured with the bitter principle of hops. Normally, they ought to contain alcohol, starch, sugar, dextrine or starch-gum, extractive and bitter matters, fatty, aromatic, and glutinous matters, lactic acid, carbonic acid, salts, and water. They are, however, often largely adulterated—molasses and other wash being used for malt; quassia and nux vomica substituted for hops; flavours imparted by capsicum, ginger, salt, and coriander; and intoxicating qualities conferred by cocculus Indicus, tobacco, and opium. Keeping out of view these adulterations, the genuine liquors are fitted by their constitution to quench thirst and act as diluents, and to operate as tonics and stimulants. Their value as nutriment, however, is not great, for even when of good quality, they contain only 9 per cent. of solids, consisting chiefly of sugar and gum. The only drawback to their use in large quantities is the intoxicating effect of their alcohol—common beer containing about 1 per cent. by measure, porter from 4 to 6, and strong ale from 6 to 8.

PREPARATION OF FOOD—COOKERY.

COOKERY is the art of preparing food. Much of our daily comfort and health depends on the way in which food is prepared. Every housewife may not be able to procure the finest kinds of food, but by attention, activity, cleanliness, and neatness, a great deal may be done to make even the plainest fare palatable and wholesome.

CULINARY UTENSILS.

Boiling and Stewing Vessels are now to be had of every size and description; the best kind—called goblets in Scotland, and saucepans in England—are those made of iron, well tinned inside. It is convenient to have one or two of the very smallest dimensions, made of block-tin; and to have several lined with delf, suited for delicate stews and other preparations. It is likewise advantageous to have a few shallow saucepans to be used for stews, or where little liquor is required; also one large and one small fish-kettle, with a flat drainer to place below the fish in boiling, and for lifting to the dish when done. All the vessels should have tightly fitting tin or iron covers; and one or two should be fitted with perforated apparatus for steaming.

The *Kitchen-range* forms the most important part of the cooking apparatus, and without one that does its work well, we cannot have our food prepared satisfactorily. Great attention should therefore be paid in choosing one and fitting it up. As a large proportion of those in use are faulty, it will be useful to give a few hints on their construction, as well to those who may have to purchase new ones, as to those who wish the ranges already in their possession improved. And first, in regard to the fire. In a moderate establishment, the *open fire* is to be preferred to the *hot plate*, because it is simpler, and consequently cheaper; and also because it is, in many respects, more economical and efficient. The great objection to an ordinary open kitchen-fire is, that it consumes a great quantity of coal, and yet can only with difficulty be got to give the 'quick' sustained heat that is required for roasting and other culinary processes. The reason why a quick fire is essential to good roasting is obvious. When we boil properly a leg of mutton, we put it into water brought to the boiling temperature, in order that the outer layer of albumen may be rapidly coagulated, and may thus form a crust, which will retain the internal juices and savour of the meat; and so also, in roasting, if we wish these retained, and the meat properly done, we must have the fire quick before the meat is exposed to it. American cooking-stoves combining the open grate and the hot plate are (1873) coming into use, but no verdict can yet be given regarding them.

Goblets, stewpans, gridirons, and vessels of all kinds used in cooking ought to be kept scrupulously clean. It is the part of the cook to see to this, and whether the kitchen be that of a great nobleman or of some humble cottager, strict cleanliness is essential to success in the culinary art: the flavour of many a fine dish has been destroyed because of the laziness or carelessness of those intrusted with the cleaning of the vessels employed.

GENERAL COOKERY.

BOILING—ROASTING—BROILING—FRYING—BAKING—STEWING.

Before entering on the preparation of particular dishes, the following remarks on what may be called the fundamental processes of cookery may be advantageously perused.

Boiling.

Boiling is the preparation of meat in water, and it is necessary that the vessel employed be large enough to allow the meat perfect freedom; if it be cramped, and have only a little water, it will be stewed, not boiled. In all cases of boiling, there must be a sufficiency of water to cover the meat. In boiling meat, there is less waste than in roasting; and in most cases, soup may be made of the liquor. One general direction to be attended to in boiling meat is, that where soup is to be made, the meat must be put into *cold* water, and very gently boiled; but when the chief object is to get the meat for eating, it is at once to be immersed in *boiling* water, and also very gently boiled—in both cases, with a closed cover.

When meat of any kind is done, and has to be lifted from the pot, take care not to put a fork into any part where there are juices; if this be not attended to, a portion of the juices will escape, and the marks of the fork will produce an unsightly appearance in the meat. All parts of mutton and lamb may be roasted, but it is usually only the leg, neck, and head that are boiled. As to time—no general rule can be laid down for the boiling of meats or fish. Dried meats, as tongues or hams, take longer time to cook than fresh mutton. As a general rule, a quarter of an hour per pound-weight may be allowed for fresh meat; and for salted meat, double that time. The water in which either fresh or salt meat is boiled, may be successfully used in the making of various kinds of broths or soups. *Steamers* are now greatly in use for the preparation of vegetables and potatoes. In hotels and other places where dishes require to be quickly served, steaming is used, but it is not a process that we can recommend.

Roasting.

Meat is roasted by being exposed to the direct influence of fire. This is done by placing the meat before a fire, and keeping it constantly in motion, to prevent scorching on any particular part. No rules can be laid down with precision as to roasting, but the proper management of the fire is half

the battle. The fire must be bright and beautifully red before the meat is put before it; care must be taken to prevent any cinder or ash from falling into the dripping-pan, and the meat must be carefully basted as it is kept turning. The meat should not be placed too near the fire, so as to be shrivelled up in the process of cooking; nor should a small bit of meat be roasted, because it shrinks away to nothing. It is not economical to roast a piece of meat weighing less than five pounds. 'Slow and equal' should be the motto of those who 'rule the roast.' A very fat roast, it may be stated, will take longer to cook than a lean one: about twenty minutes per pound-weight is as near as possible the time to make ready meat at a roasting-fire. Some meats, as veal and pork, take longer than beef and mutton; but observation alone can educate the cook in the niceties of time.

Broiling.

Broiling is the rapid cooking of any kind of animal food by the influence of fire. The apparatus required in broiling is very simple, and consists only of a gridiron, whose bars should be small, and kept thoroughly clean, both on the tops and sides. An improved form of gridiron consists of channeled bars leading to a trough or receptacle for the exuded juices. Let the iron be heated for a minute before placing the meat upon it; and rub the warm bars with a piece of brown paper, to prevent the meat from sticking to them. The operation of broiling requires a clear strong fire with no smoke. In almost all cases, the meat ought to be frequently turned, which may be best done by a pair of small tongs; a fork should on no account be used in turning, for it breaks the skin of the meat, and allows the gravy to run out. Broiling possesses the peculiarity of being applicable only to meat which is to be eaten immediately on being dressed. This is an advantage when expeditious cooking is required, but a disadvantage when there is any uncertainty as to the time at which the meat is to be eaten. Broiling is not so economical a method of cooking as boiling, a great proportion of the nutritious juices being discharged from the flesh beyond means of recovery.

Frying.

Frying is as expeditious a mode of cooking as broiling, requires less activity and care, and is more thrifty. It affords a ready means of dressing in a savoury manner many odd pieces of uncooked or cold meat, thereby saving that which might otherwise have been thrown away as useless. A skilful housewife, with the aid of a frying-pan and some cheap vegetables, such as onions and potatoes, along with a slight seasoning, will make a small portion of meat dine a large family. A frying-pan should be of malleable, not of cast iron. It should also be thick in the bottom, and of an oval form. It should be kept very clean, by being washed with boiling water, but not scoured. In using it, a small piece of dripping, butter, or lard, must be put into it, and melted, to prevent the meat from adhering to it. In frying all meats, excepting those which are sufficiently fat in themselves, it is necessary to use some kind of grease or fat. The best fat for this purpose is lard, which is more economical, and less likely to burn than butter. When lard is not employed, the best substitute for it is dripping. All the smaller kinds of fish are excellent when fried.

Baking.

Meat is prepared for baking in the same manner as for roasting. It should be placed in a deep dish for receiving the fat which flows from it; not laid, however, on the sole of the dish, but raised on a stand, to prevent the grease soaking into it. Small iron stands are made and sold for this purpose. Few dishes are so good when baked as when roasted, the meat being so liable to be shrivelled for lack of basting; and being liable, moreover, if done in a baker's oven, to partake of the flavour of the multifarious articles which are there prepared. Perhaps the only dishes which are better baked than roasted are bullock's heart and leg of pork, because in roasting they are liable to be scorched on the outside before they are thoroughly cooked in the inner parts.

Stews, Hashes, and Made Dishes.

Stewing is the preparing of meat by slow simmering, all the liquor being used along with the meat at table. This is a much more savoury and nutritious mode of cookery than boiling, because the substance of the meat is partly in the liquor, and is seasoned to have a high relish or flavour. Generally, much more can be made of meat by stewing than by roasting, boiling, or frying, because nothing is lost in the process of dressing. It also possesses the decided advantage of being a way by which meat may be dressed for a person whose time of dining is uncertain. A stewed steak, for instance, will keep warm and in good condition for an hour, but a broiled or fried steak must not be kept a minute after dressing.

SOUPS.

Soups are the substance of meat infused in water by boiling, and are of many different kinds, but may be divided into two classes—namely, *brown* and *white*. The basis of brown soups is always beef, while the basis of white soups is generally veal, or the trimmings of the more gelatinous fishes. Broths are of the nature of soups, but more simple in their composition, and usually containing some kind of vegetables or matter for thickening. Soups and broths are much less used in England than in Scotland or on the continent.

Brown Soup—Stock.

Brown or gravy soup forms the stock or basis of all soups of the brown kind. It is thus made: Take a shin or piece of the rump of beef, and cut it in several pieces. Cut the beef from the bones; take out part of the marrow, and lay it on the bottom of the pot. If there be no marrow, use butter. Then lay in the meat and bones to brown. Turn the whole when browned on one side, and take care that it does not burn. When it is thoroughly browned, add a pint of cold water to draw the juice from the meat, also a little salt; and in a quarter of an hour after, fill in the quantity of cold water which may be requisite. Now add the following vegetables, two carrots, a turnip, and three or four onions, all sliced; also a stalk of celery, some

sweet herbs, with some whole black and Jamaica pepper. Let the soup boil slowly for about five hours, after which take it off, and let it stand a little to settle. Then skim off the fat, and put it through a hair-sieve to clear it. The soup, if cleared, may now be either served or set aside for after-use. It should have a clear bright look, with a brownish tinge. Brown soup thus prepared forms any kind of vegetable soup, by merely adding to it, when just finished boiling and clearing, the particular vegetable which may be required.

Kidney Soup.—Cut a pair of kidneys into slices, wash in boiling water, and dry with a towel. Have the frying-pan ready, with hot lard or dripping, into which put the sliced kidneys, the flour of a grated potato, a few onions, a dessert-spoonful of Jamaica pepper, and a little salt. Stir with a spoon, and brown nicely. Cut the kidneys into small pieces; add this to a gallon of water, and grate into it half a carrot, and the same size of turnip, and boil with closed cover very gently for four hours. Carefully skim off the superfluous fat. If wished particularly good, a pound or so of hough of beef may be added, or half a pint of brown soup. With less water, and omitting the carrot and turnip, this makes a delightful stew.

Ox-tail Soup.—Take two ox-tails, cut into pieces, along with a couple of pounds of hough or shin beef, and put into a gallon of water, with two or three onions, a grated carrot and turnip, pepper and salt; and boil very gently, with closed cover, for four hours.

Mock-turtle Soup.—This is made with a calf's head, which obtain ready scraped and cleaned from the butcher, but with the skin on. Put it into a pot with considerably more water than will cover it. Skim it frequently as it warms, and let it boil gently for an hour. Take out the head, and when it has cooled, cut the meat off in handsome pieces of about an inch square. Scrape and cut the tongue in the same manner. Lay all these pieces aside. Then put into the water in which the head was boiled about three or four pounds of shin of beef and a knuckle of veal, with the bones broken. Add to this four or five onions, a carrot and turnip sliced, a small bunch of sweet herbs, and some black and Jamaica pepper, whole. Add also the brains, after you have boiled them separately in a cloth, and pounded them. With all these additions, let the soup boil slowly for four or five hours; after which, strain it, and when cool, take off the fat. Take a quarter of a pound of fresh butter, and melt it in a stewpan; when melted, put in two handfuls of flour, and let it brown, stirring it all the time; add a little of the soup, a sprig or two of sweet basil, and a few heads of parsley. Boil this for a quarter of an hour; strain it through a sieve; then put this, the pieces of meat, and the soup, all together, and boil it for an hour. Add two tablespoonfuls of ketchup, the juice of a lemon, Cayenne pepper, and salt to taste. It is usual to put in at the same time four glasses of sherry wine. When dishing, add two dozen of egg-balls.

Veal Soup.—Some very rich white soups are made from veal, but the following is a comparatively inexpensive soup. Take a good-sized knuckle of veal, and put to it four quarts of water, with an onion or two; when it has gently boiled an hour, add two tea-cupfuls of rice, and let it simmer for two hours. A quarter of an hour before it is ready, add a little minced parsley. Serve the veal separately, with melted butter, garnished with parsley.

Scotch Soups.

Some of the best soups are peculiar to Scotland, more especially the national dish of barley-broth, 'sheep-head kail,' 'cockie leekie,' hotch-potch, and hare soup.

Barley Broth is made once or twice a week in nearly every cottage in Scotland, and even in houses of greater pretension it is greatly used. It is made as follows: Take two or three pounds of a neck of mutton, or the same quantity of the shin or hough of beef, or of the flank or nineholes of beef, and put it on the fire with one gallon and a half of water—adding a morsel of washing-soda where the water is the least hard—two tea-cupfuls of barley, and the same of dried green peas. Take also a large Swedish turnip, or two or three smaller ones, two carrots, three leeks, a moderately sized savoy or cabbage, and clean well and mince small on a mincing-board, grating portions of the carrot and turnip, reserving some sizable portions for serving with the meat. Boil the whole very gently for three and a half hours. The cover should be kept perfectly closed, and whenever steam is seen to escape, the pot should be removed a little from the fire. Without strict attention to this last direction, the broth never can be properly made. Where hough or beef is used, it should previously have lain in salt for three or four days, as this improves both the broth and the flavour of the meat. A quarter of an hour before the broth is ready, add a little minced parsley. Serve the meat with pieces of the carrot and turnip, and a little of the thin of the broth as sauce.

Sheep-head Broth is made in exactly the same way as the above, the boiling being continued a little longer. The head should have a pound of the neck attached to it, and should be bought ready 'singed,' and should then be scraped and sawn open, the internal parts well cleaned, and the whole soaked all night in water. The head and trotters should be served with pieces of carrot and turnip, and some of the thin of the broth. To preserve the true flavour, it is of importance that the 'scraping process' should not be carried too far. The feet, when well boiled, are said in Scotland to be the best part of the head!

Hotch-potch is made in the same way as barley broth, omitting the barley, and using young green peas, Turkey beans scalded and skinned, carrot and turnip, lettuces, young onions and parsley. The vegetables must be well boiled, or the soup will be spoiled. A neck of mutton may be used, or lamb-ribs, cut up and served with the soup.

Scotch Hare Soup.—This excellent soup is made as follows: The stock must be prepared by boiling, say three pounds of beef—hough is best—along with an onion or two, three small sticks of celery (or a little bag of celery-seed), a sprig or two of thyme, and a few Jamaica peppercorns; when this is ready, that is, when the beef is boiled to rags, strain off the liquor, and keep it till wanted. Having skinned and gutted your hare (a snared or coursed one is best, as it contains a greater quantity of blood than one that has been shot), cut it into sixteen or twenty pieces, preserving carefully all the blood; place the

pieces in a basin, with four or five quarts of cold water, till required to be cooked; they may stand all night if necessary; when wanted, place them in a goblet of sufficient size, and set on the fire, taking particular care to stir the compound till it is thoroughly boiling; whilst it is being stirred, the flour of a grated potato may be added. After the soup has come to the boiling-point, pour in the stock gradually, and then let the whole simmer for two hours. Dish with the pieces of hare in the tureen. Some cooks add a glass or two of port wine before the soup is served, others a pint of porter; but, if a full-blooded hare has been obtained, the flavour will be sufficiently powerful without these adjuncts.

In making the above and most other soups, sufficient time must be given for the extraction and diffusion in the fluid of the juices of the meat and vegetables. A good plan, to save both fuel and trouble, is, where the size of the family admits of it, to have a pot sufficiently large to make broth for two days, and to heat the broth slowly on the second day. The cost of a large potful of barley broth may be set down, at present prices, as about 2s. 6d.—that is, 2s. for beef, and 6d. for vegetables and firing. The cost of a sheep's head and trotters is 1s.; which, with 6d. for vegetables and firing, makes a cheap dinner, considering that it will dine six or seven people.

Peas Soup.—Take two or three pounds of a shin or hough of beef, and put into a gallon and a half of water, with a bit of washing-soda the size of a large nut, two pounds of split peas, a moderately sized carrot and turnip, two or three onions, and a little celery-seed tied in a bit of muslin. When the carrot and turnip are boiled soft, mash, and return them to the pot. Boil with closed cover, very gently, for four hours. When ready, strain through a sieve, and serve with hard toasted bread, cut into dice, and thrown into the soup in the tureen, so as to preserve its crispness. This soup may be made with bones or trimmings, or roast-beef dripping, the liquor a ham or any meat has been boiled in, or even without any of these, by frying the bread in plenty of lard before cutting it into dice. Its best seasoning is curry-powder. Vinegar added before serving, or at table, in the proportion of about a teaspoonful to each plateful of soup, is thought by many to improve its flavour, and certainly promotes its digestibility; it also removes in a great measure one great objection which many have to this fine soup—namely, the formation by it of flatus in the stomach and bowels.

Cockie Leekie or *Cock-a-leekie* is a famous Scottish soup. It is made by boiling three pounds of hough till all the strength is taken out of it. After that, take out the refuse of the beef, and add to the gravy a fowl, jointed or cut in small pieces; then put into the goblet plenty of leeks, well cleaned, and cut into small portions: it is as well to boil down a leek or two in the stock. Season with pepper and salt to taste: the soup must be well boiled.

FISH.

The price of fish of all kinds has, in recent years, increased enormously. A quarter of a century ago, a fine haddock might have been obtained for a few halfpence, and to pay a shilling for a large cod-fish was thought extravagant, whilst fresh herrings were considered dear if they exceeded threepence a dozen. Now, a good-sized cod-fish at Christmas-time has been known to cost a sovereign, and oysters for sauce will be half as much; whilst turbot, salmon, and some other fishes sell at prices which place them altogether beyond the reach of any but rich people—if we except occasions of a glut in the market, when fresh herrings, mackerel, or flounders may be bought at a reasonable price.

Choosing Fish.—If the purchaser can afford to buy fish at a first-rate fishmonger's shop where a continuous trade is carried on, the selection or recommendation of particular kinds may be very safely left to the dealer, who, for the sake of his business reputation, will do nothing wrong, and who, from the great and constant demand made at his shop, is sure to have his stock in an invariably fresh and wholesome state. To those compelled to buy in the open market or from hawkers, the following directions may prove useful. As a general rule, the freshness of a fish may be tested by the brightness of the eyes and the redness of its gills. Line-caught ground fish are always the best; those taken by the trawl have a hashed appearance, in consequence of the slime and scales being rubbed off. The largest cod-fish, as a general rule, are best. When fish are turning stale, the redness of the gills begins to fade, the sides grow dull, and the fish becomes limp. A fine fish is always 'bent stiff' when in good condition. Fish full of milt and roe are not good for food, as all the flesh-forming properties have been abstracted to swell the spawn; but, unfortunately, it is at the spawning period that most of our best fish are obtained.

Fish are dressed in a variety of ways, according to taste. They are boiled, broiled, baked, stewed, and fried; but the most common modes of preparation are boiling and frying—boiling when required to be done in a plain way, and frying when a high relish or flavour is to be given to them. In all modes of preparing fish, much care is required to prevent them from being broken or disfigured.

To fry Trouts or similar Fish.—Trouts of a moderate size are dressed whole, and frying is the best mode of preparation. Take the trouts, and clean out and scale them. Dust them with flour or oatmeal, and put them in a frying-pan with hot dripping or lard. Turn them, so as to brown them on both sides. Lift them out, and serve them on a dish; they will be improved by laying a napkin under them, to absorb the grease. In the country parts of Scotland, trouts are dipped in oatmeal instead of flour, and some reckon that this improves the flavour.

To dress a Cod's Head and Shoulders.—Take a cod's head and shoulders in one piece, which clean, and let lie among salt all night. When you are going to dress it, skin it, and bind it with tape, to keep it firm. Put it in a fish-kettle, back upwards, with plenty of cold water, a handful of salt, and a little vinegar. Let it heat slowly, and boil for about half an hour. Then let it lie on the drainer across the top of the kettle, for the water to drip from it. After this, place it, back upwards, on the dish in which it is to be carried to table, cutting and drawing away the tapes very carefully. Brush it over with beat egg, strew crumbs of

bread, pepper, and salt over it, and stick pieces of butter thickly over the top. Set it before a clear fire to brown. A rich oyster sauce, made with beef gravy instead of water, and highly seasoned with Cayenne pepper, salt, and ketchup, is poured in the dish around the fish. Do not thicken the sauce with flour.

To dress a Middle Cut of Cod.—Clean the piece of cod, and make a stuffing of bread-crumbs, parsley, and onions chopped small, pepper and salt, a bit of butter, moistened with egg. Put this stuffing into the open part of the fish, and fix it in with skewers. Then rub the fish over with beat egg, and strew crumbs of bread, pepper, and salt over it. Stick also some bits of butter on it. Set it in a bachelor's or Dutch oven before the fire to bake. Serve with melted butter or oyster sauce.

To boil Haddocks, or a cut of Cod.—This is the simplest of all operations. Clean the fish well, and wash and boil with a little salt in the water, the first for twenty minutes or half an hour, the other for about three-quarters of an hour. Eat with oyster sauce, or melted butter and ketchup.

Fillets of Haddocks.—This is a most delicious dish when well prepared. Take pretty large haddocks, which clean and wash well. They will be firmer and better if they lie for a night in salt. When to be dressed, wash them and dry them. Cut off the head, tail, and fins; then skin them, being careful not to tear the flesh. Cut the flesh neatly from the bone, and divide each side into two pieces. Dust them with flour, dip them into beat egg, and strew bread-crumbs over them. Fry them in a frying-pan, with a sufficiency of hot dripping or lard to cover them. Be careful that the dripping is not hot enough to scorch the fish. The way to ascertain the proper degree of heat of the fat is to dip a thin slice of bread into it, and when it makes the bread of a light-brown tinge, put in the fish. If the fat be too hot, it will make the bread of a deep brown. Turn the pieces carefully, so as to brown both sides, and when done, lay them before the fire on a drainer for a few minutes. Serve in a dish, garnished with parsley. Sauce—oyster sauce, or with a little ketchup added. The fat in which haddocks are fried will serve again, if put through a hair-sieve, and poured in a jar, and kept in a cool place.

To fry Skate, Soles, Flounders, Whitings, and Eels, or any other White Fish.—Skate and soles are skinned and dressed in the same manner as haddocks, but soles are usually fried whole, not cut in pieces; large ones may be cut into halves. Flounders are fried in the same manner, whole, but do not require to be skinned. Eels must be skinned and cut in pieces.

To bake Haddocks.—Take two or three haddocks, gut and clean them, and lay them all night among salt. When to be used, skin them, and cut off the heads, tails, and fins. Make a stuffing of bread-crumbs, chopped onions, and parsley, and a little bit of butter. Sew this into the bellies of the fish. Rub them over with butter, strew bread-crumbs over them, and bake them in an oven or before the fire.

Fish and Sauce.—Take two or three haddocks, gut and clean them, and lay them all night among salt. When to be used, skin them, cut off the heads, tails, and fins. Boil these trimmings for three-quarters of an hour in a little water. Brown a little flour and butter in a stewpan, and then strain the liquor, and put it to the butter; add sliced onion, chopped parsley, salt, a little Cayenne pepper, and a spoonful of ketchup. When all this has been boiled for a few minutes, cut the fish in pieces, and let it boil gently till it is ready. With a little white stock and more water, this may be called, and is, an excellent fish soup.

To scallop Oysters.—Scald the oysters in their own liquor. Pick them out of the liquor, and lay them in a dish, or scallop-shells, or tins, strewing crumbs of bread mixed with pepper and salt over each layer, and finishing with crumbs. Moisten the whole with a small quantity of the liquor in which the oysters were scalded, and stick pieces of butter thickly over the top. Place the dish before the fire to bake. From ten to twenty minutes will be required, according to the quantity.

Sprats, which are very plentiful throughout some of the winter months, form a cheap and palatable addition to the dinner-table. They are excellent when boiled in salt-water, and served cold with a little vinegar. They are very good when fried. Clean them and wipe them dry, then dip them in oatmeal, and fry in lard or beef-dripping till they are of a nice light-brown colour. Small sprats are as nice as whitebait, which fish, in fact, is the young of the herring, or the sprat. The whitebait served at the tables of fashionable taverns in London is a mixture of the young of various fish.

Fresh Herrings as at Inverary.—Cut off the heads, fins, and tails, scale, gut, and wash the herrings. Split them open, and dust the inside with fine pepper and salt. Place two herrings flat together, the backs outmost, then dip in toasted oatmeal, and fry in dripping for seven minutes.

Boiled Herrings.—The Loch Fyne fresh herring is never more delicious than when boiled in water which contains plenty of salt. Salt herrings, when to be eaten with potatoes, should be boiled upon the top of the potatoes. They are excellent, done in this manner.

Mackerel may be cooked much after the same fashion as fresh herrings. They are excellent broiled and eaten with a little pepper and salt, and they are never better than when they are boiled with plenty of salt in the water.

ENTRÉES, OR MADE DISHES.

Stewed Veal.—Take two pounds of any fleshy part of veal, and cut into neat pieces. Have an egg beat up, and some bread-crumbs, with minced parsley, onions, white pepper, and salt, on a plate. Have some lard or dripping in the frying-pan. Dip the cut veal in the egg, and then in the crumbs, and fry till the veal is of a nice light brown. Put in a stewpan with a little water two tea-spoonfuls of flour, an onion, a little parsley, and two slices of lemon, and stew slowly with closed cover for an hour. Serve slices of lemon round the dish.

Curried Rabbit, &c.—Cut a rabbit into pieces, wash well, and put in a stewpan with a quarter of a pound of butter, a dessert-spoonful of curry-powder, and three or four large onions, and as much water as will cover the meat. Stew slowly with closed cover for two hours. Half an hour before dishing, add a table-spoonful of flour moistened with cold water. Eat with potatoes, and rice prepared as follows: Take a breakfast-cupful of rice, wash till the water runs clear, and

put on with just as much water as will cover it, adding a little salt. Let it simmer very slowly with closed cover, without stirring it, for an hour and a quarter. It should be quite dry when dished. Excellent curries may be made in the same way by using fowl or chicken, fish, ox-heart, or any cold meat. The fish and cold meat will be ready in half an hour; the ox-heart ought first to be parboiled, and requires two hours to make it ready. If the curry-powder is omitted, these dishes are all stews.

Mutton Haricot.—Take a pound of mutton-chops, beat, and brown in the frying-pan with lard or dripping. When browned, put in a stew-pan, with just as much water as will cover the meat, pepper, salt, a sliced carrot, a turnip, and two or three onions. Stew slowly for an hour and a half, adding a dessert-spoonful of flour, moistened with a little water, a quarter of an hour before serving. These dishes, however well cooked, will yet lose half their relish if served in a slovenly manner, or when allowed to get cold and out of season. Where the meats are hot, they should always be dished and served quickly, and especially always be eaten from heated plates.

Dressed Sheep's Pluck.—Take a sheep's heart, lungs, and half of the liver, and parboil. Mince fine with two or three onions, parsley, pepper, and salt. Put in a stewpan with a handful of flour and half a pint of water. Stew slowly with closed cover for an hour and a half. Cut the rest of the liver into thin slices, fry with fat bacon, and serve round the stew.

Beef-olives.—Take a pound of beefsteak, and cut into three pieces, mince a little bit of suet with an onion or two; sprinkle this over the steak, with a little Jamaica pepper, black pepper, salt, and a little flour, and roll each piece up, and tie with a bit of thread. Put into a stewpan, with a little water, a tea-spoonful of Jamaica pepper, a morsel of butter, a table-spoonful of flour, and stew slowly with closed cover for an hour and a half.

Minced Collops.—Get a pound of steak minced very small, along with a bit of suet—the butcher will do the mincing—put on in a stewpan, with a good handful of flour, pepper, salt, and a very little drop of water. Have a wooden spoon, and shuffle all the time they are cooking, to prevent lumps forming. They should be quickly made ready. As soon as they fairly boil all through, dish and serve. Eat with mashed potatoes.

ROAST AND BOILED MEATS.

Following the usual course of the British dinner-table, we now come to what may be called the *pièces de résistance*, or back-bone of the dinner, or what the cook calls 'the roasts and boils,' which include all the larger joints.

Roast Meats.

To roast Beef.—The best piece of beef for roasting is the sirloin. If the suet be not required, it may be ordered to be cut off before purchasing the joint; a small piece of suet is all that is requisite for the purpose of basting. If at all musty, it should be washed with salt and water, and wiped quite dry. Hang it on the hook of the jack, in the way most advantageous for being operated upon uniformly by the fire. Handle it as little as possible. The fire must be quite clear and brisk. It is customary to allow a quarter of an hour for every pound of the meat. While roasting, baste it very frequently with its own dripping. In dishing, pour a little boiling water and salt over it for a gravy. A well-roasted joint ought to have a nice rich brown tinge, and this is to be obtained only by careful basting, attention to the fire, and removing at the proper time, when experience tells that the joint is 'done.' Garnish with scraped horse-radish.

To roast Mutton.—The best parts of mutton for roasting are the leg, the shoulder, and the loin. The piece may be kept longer than would be desirable for mutton for boiling. It should have a clear and brisk fire. A leg will take two hours to roast; but this, as well as the time for roasting the other parts, must be regulated by the fire and the weight of the meat, and can be learned only by attention. The joint of mutton should be basted the same as beef, with its own dripping, and a gravy should be made for it as above.

To roast Venison.—Venison is roasted in the same manner as mutton, but requires longer time at the fire. It is such a dry meat, and the fat is so easily melted, that it should be covered with buttered paper, and well basted. Serve with good gravy and currant jelly.

To roast Veal.—The best parts of veal for roasting are the fillet, the breast, the loin, and the shoulder. The fillet and the breast should be stuffed, particularly the fillet, with a composition of crumbs of bread, chopped suet and parsley, a little lemon-peel, and pepper and salt, wet with an egg and a little milk. Let it be well basted with butter when there is not sufficient dripping from the joint. The gravy for roast veal is either the usual hot water and salt, or thin melted butter, poured over the meat.

To roast Lamb.—Lamb also requires to be well roasted. It is usually dressed in quarters; all parts, particularly the spinal bone, should be well jointed or cut by the butcher or cook; and the ribs of the fore-quarter broken across the centre, in order to accommodate the carver. In roasting, baste, as already described, with its own dripping. The gravy for lamb may be the same as for beef or mutton. A very nice stuffing for lamb is often used in Scotland: mince some of the suet, an onion, and a few blades of parsley, and mix with a handful of oatmeal, a little pepper, and a very little salt. Make a hole in the loose skin of the loin, fill with the above, and sew up. Mint sauce should be served with the lamb.

To roast Bullock's Heart.—Wash the heart well, freeing it completely from blood. Then fill all the openings at the top or broad end with stuffing composed of crumbs of bread, chopped suet, parsley, pepper and salt, moistened with an egg and a little milk. Suspend with the pointed end downwards. An hour and a half, or two hours, according to the degree of heat, will cook the dish, which should be well done. Serve with beef gravy.

To roast Pork.—Pork requires a longer time in roasting than any of the preceding meats. When stuffing is to be used, it must be composed of chopped sage and onion, pepper and salt. The pieces should be neatly and well scored in regular stripes on the outer skin, to enable the carver to cut slices easily. Before putting to the fire, rub the skin with salad-oil, to prevent its blistering, and baste very frequently. The basting may be

done by rubbing it with a piece of butter in a muslin bag, where there is not enough of dripping. The gravy for pork may be the same as for other joints, hot water and salt poured over it on the dish. Apple sauce served in a small tureen assists in overcoming the richness or lusciousness of the meat, and imparts an agreeable flavour.

To roast Fowls.—Pick, draw, and singe them. A fowl should be so cleanly or well drawn as to require no washing. Take care not to break the gall-bag in drawing; if the gall be spilled, it will communicate a bitter taste to every part it touches. Press down the breast-bone. Break the legs by the middle of the first joint, drawing out the sinews, and cutting off the parts at the break. It being proper that roast fowls should have a neat appearance at table, it is customary to *truss* them—that is, to fix their legs and wings in a particular position. This is done by fixing down the knees of the animal close to the tail by a skewer or piece of string, leaving the stumps of the legs projecting. The pinion ends of the wings are then turned round on the back, the liver being placed as an ornament in one wing, and the gizzard in the other. Cut the head off close to the body, leaving a sufficiency of the skin to be tied or skewered on the back. Baste well with butter for some time after putting to the fire. Suspend neck downwards. The time of roasting will vary from half an hour to an hour. When a fowl is large, it is frequently stuffed like a turkey. Serve roast fowls with melted butter or a sauce made of the neck, the liver chopped, a little butter and flour. Before sending to table, remove all skewers and strings which may have been used in trussing. This, which should be done in all cases of sending dishes to table, is too frequently neglected, and shews slovenliness in cookery. Fowls and all other feathered animals are served with the breast upwards.

To roast Turkey.—Pick, draw, and singe the turkey well. Press down the breast-bone, and follow all the directions given for trussing fowls. The breast should be stuffed with crumbs of bread, minced beef-suet or marrow, minced parsley, a little nutmeg, pepper, and salt; wet it with milk and egg; a little sausage-meat may also be added. On finishing, sew up the orifice or neck. Before putting to the fire, cover the breast with a sheet of writing-paper well buttered, to preserve it from scorching, and which may be removed a short time before taking from the fire, to allow the breast to be browned. Baste well with butter. A turkey will take from an hour and a half to two hours. Serve with gravy-sauce.

To roast Pigeons.—Pick and draw them well, and truss, keeping on the feet. Make a stuffing of the liver chopped, crumbs of bread, minced parsley, pepper, salt, and a little butter; put this inside. Make a slit in one of the legs, and slip the other leg through it. Skewer and roast them for half an hour, basting them well with butter. Serve with beef gravy in a small tureen, and on toast-bread placed under them while roasting, to catch 'the trail.'

To roast Partridges and other Game.—Pick, draw, singe, and clean these birds the same as fowls. Leave the head on, make a slit in the neck, and draw out the craw. Twist the neck round the wing, and bring the head round to the side of the breast. The legs and wings may be trussed in much the same manner as fowls. The feet are left on, and crossed over one into the other, as seen in the annexed figure. Baste well with butter before a clear fire. When about half done, dust a little flour over them to be browned. A partridge will take from twenty minutes to half an hour, and a pheasant three-quarters of an hour. Serve on toasted bread, with gravy, as above. Grouse and black-cock should be dressed and served in the same manner; the head being trussed under the wing. Snipes and woodcocks are not drawn.

Fig. 1.

To roast Goose.—Pick, draw, and singe the goose well. Cut off its head and neck. Take off the legs and wings at the first joint. The portions of the legs and wings that are left are skewered to the sides. Stuff with chopped sage and onion, and crumbs of bread, with pepper and salt. The skin of the neck must be tied securely, to prevent the gravy from running out. Paper the breast for a short time. A goose does not require so much basting as fowl or turkey, for it is naturally greasy. It will require from two hours to two hours and a half in roasting. It ought to be thoroughly done. Serve with gravy sauce and apple sauce. The liver, gizzard, head, neck, feet, scalded and skinned, and the pinions of the goose, form what is termed the *giblets*, and compose a good stew or pie.

To roast Ducks.—Pick, draw, and singe them well. Take off their heads. Dip their feet in boiling water, to take off the outer yellow skin. Truss them neatly, turning the feet flat upon the back. Stuff as in the case of goose, and serve with the same sauces. A duck requires fully an hour to roast.

To roast Hare.—A hare will keep with the skin on it, and paunched, for two or three weeks in cold weather. It is then fit for roasting. First cut off the feet, and commence drawing off the skin at the hind-legs, proceeding along the body to the head. Be careful not to tear the ears in skinning them. Soak and wash well in several waters, and then wipe quite dry. Stuff with crumbs of bread, chopped parsley, a bit of beef or veal suet chopped finely, a little grated lemon-peel and nutmeg, a piece of liver boiled and finely chopped or grated, and pepper and salt; the whole moistened with

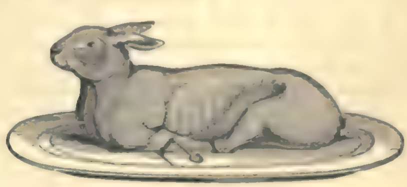


Fig. 2.

an egg, a little milk, and a spoonful of ketchup. The skin of the belly afterwards to be sewed. Commence trussing, by placing the hind and fore legs flat against the sides. To make the hind-legs lie flat, the under sinews must be cut. Fix the head between the two shoulders, on the back, by running a skewer through it into the body. In roasting, suspend head downwards. It should

be basted first with milk, afterwards with butter, flouring it lightly. It will require from an hour and a half to two hours. The hare is dished back upwards, as represented above, and served with rich beef gravy, and a dish of currant jelly.

Boiled Meats.

To boil a salted Round of Beef.—If large, cut out the bone, roll up firmly, and bind with a tape; then put it into the pot, and keep the lid close. Boil it slowly and equally, allowing a quarter of an hour for each pound of the beef. The appropriate garnishing for this and other pieces of boiled salt beef, is carrot and small greens; some add turnips. Put a little of the liquor in which it has been boiled in the dish.

To boil a Leg of Mutton.—A leg of mutton should be kept four or five days before boiling. Before putting it into the pot, bend round the shank, cutting the tendon at the joint, if necessary, so as to shorten the leg. Two hours of slow equal boiling will be sufficient for a good-sized leg of mutton. Some persons, to make the leg look white and tasteful, wrap it tightly in a cloth in boiling; but this spoils the liquor for broth. It is not safe to boil vegetables with a leg of mutton, as they are apt to flavour the meat. Dish the leg with a little of the liquor, placing the lower side uppermost, conveniently for carving. A good leg of mutton will soon yield sufficient gravy. For sauce, use finely chopped capers in melted butter. Mashed turnips form an appropriate vegetable to be eaten with this dish.

To boil Veal.—Veal is seldom boiled, being too insipid by that mode of dressing. The only part boiled is the knuckle, which requires much boiling, in order to soften the sinews. It is eaten with boiled ham or bacon. The sauce used is parsley and butter. The liquor from veal is the best of any for making soup.

To boil a Turkey.—Boiled turkey is one of the most delicate and excellent dishes which can be brought to table, and should be dressed with as much care as possible. Clean the turkey from all feathers, and singe the hair with burning paper, being careful not to blacken the skin. Clean it well inside by drawing and wiping. Cut off the legs at the first joints, and draw out the sinews; then pull down the skin, and push the legs inside. Cut off the head close to the body, leaving the skin long, and draw out the craw. Make a stuffing of chopped suet, crumbs of bread, chopped parsley, pepper, salt, and a little nutmeg, which wet with an egg and milk. Put this stuffing into the breast, leaving room for the stuffing to swell; after which draw the skin of the breast over the opening, and sew it neatly across the back; by which means, when the turkey is brought to table with its breast uppermost, no sewing will be seen. Place the liver in one wing, and the gizzard in the other, turning the wing on the back, and fixing the wings to the sides with a skewer. The turkey being now ready for the pot, put it into a cloth, and boil it for a length of time, according to the size and age. A small young turkey will not require more than an hour and a half; an old and larger one, perhaps two and a half or three hours. Let the water be boiling in putting in, and of sufficient quantity to keep the turkey always covered. When done, and placed in a hot dish, pour a little sauce over the breast, and put the remainder in a sauce tureen. The sauce used is various. One of the most delicate and agreeable sauces is made of melted butter, boiled macaroni, and milk.

To boil a Fowl.—A fowl is to be prepared for boiling in the same manner as a turkey, except that no stuffing is used. It may be boiled with or without a cloth. Small fowls will require from half an hour to three-quarters of an hour; large fowls will require from an hour to an hour and a half. Sauce, parsley and butter.

To boil Rabbits whole.—Wash them well in warm water. They may be either stuffed or not stuffed, according to taste. When stuffing is required, make it of crumbs of bread, suet, parsley, and onions—all chopped—and pepper and salt; moisten with milk, and simmer it very slowly, for quick boiling hardens it. It should be cut into moderately sized pieces for helping at table. When to be served plain, carry to table in a hash-dish, in some of the water with which it has been boiled, with boiled onions in it. A tasteful way of serving is to take it from its liquor after boiling, and stew it for about ten minutes in a saucepan with milk, which thicken with a little arrow-root, or flour and butter, and season with pepper and salt, immediately before dishing, as otherwise the salt is apt to curdle the milk. This makes a delicious and cheap dish.

To boil a Ham.—If the ham has been cured long, it may require soaking in cold water to soften it, from twelve to twenty-four hours before dressing. Put it in a large boiling vessel, with plenty of cold water, and let it simmer slowly from two to four hours, according to the size. Skim frequently, to remove the grease which is constantly rising to the top. When done, skin, and strew bread-raspings over the upper side; place before the fire to dry and brown. Garnish with green vegetables.

To boil a Tongue.—If hard, soak the tongue in water all night before using. Boil it from two hours and a half to three hours. Skin it before dishing. Garnish with greens or spinage.

MEAT PIES.

Beefsteak Pie.—Take three pounds beefsteak, beat it and roll in small pieces, previously sprinkling with Jamaica and black pepper, salt, and minced onions. Place in a pie-dish with more sliced onions, pepper, salt, and as much water as will fill the dish. Cover with a paste made as follows, which will also answer for tarts: Take a pound of flour, and mix with it a heaped tea-spoonful of Borwick's baking-powder—put in a bowl, and mix with this a quarter of a pound of lard, butter, or dripping, and rather more than half a tea-cupful of water. Stir round in the bowl with a spoon, and then roll over and over with the rolling-pin till smooth. Cut the paste out the size of the dish, roll out the parings, and cut them into strips. Wet the edges of the dish, and place these strips neatly round on the edges, as a foundation for the cover. Then, after putting in the meat, lay the cover on the dish, pressing down the edges closely to keep all tight. If any paste remain, cut or stamp it in ornaments for a decoration to the cover. Bake immediately in a hot oven for an hour and a half. Before serving, add a little boiling water for gravy.

Pigeon Pie is made in the same way, putting a

pound of steak in the bottom of the dish, and seasoning only with black pepper and a very little onion. The pigeons must be cleaned well, a bit of butter rolled in pepper and salt put in each, and the gizzard, liver, and heart along with them.

Rook or Crow Pie is also made as above, putting a piece of fat bacon in each, and in the bottom of the dish, instead of the steak. The rooks—which should be young birds—have to be skinned, and care must be taken not to burst the gall-bladder in gutting them.

Veal Pie is made in the same way, with bacon, the seasonings being white pepper, salt, parsley, a little bit of onion, and a slice of lemon, keeping out the seeds of the latter and the end portions of the rind. *Chicken Pie* is made with the same seasonings.

SAUCES, PICKLES, AND FLAVOURS.

Sauces are liquid preparations, to be used in giving a flavour or relish to dishes, and are of various kinds. A number are formed of melted butter, with an infusion of some other ingredients; others are in the form of gravies drawn from fresh juicy meat; and a third kind are composed partly of water, and some preserves, condiments, or spices. There is little merit in making a good sauce when a person has good and proper materials to make it with; the chief merit consists in furnishing a fine flavour from inadequate materials; as, for instance, giving a rich flavour of meat to a mass of potatoes, or some other plain dish, when no meat has been employed. This can only be done by knowing the qualities of various vegetable products, and how these may be made to resemble the juices of animal food. The vegetable products of which by far the most can be made by a skilful cook are onions, mushrooms, and carrots. Onions and mushrooms alone furnish the most effectual substitutes for animal juices, and may be dressed so exquisitely as hardly to be distinguished from the gravy of beef.

Onion Flavour.—Onion flavour is made by stewing. Take several large onions, and remove the thin outer film from them. Put them in a saucepan with a little salt and flour, and a small piece of butter or dripping, to prevent their burning. Cover them quite close, and set by the fire to brown and stew gently. Two hours will dress them, and at the end of this time they will be quite soft, and, with the addition of a little water, they will yield a rich gravy. This may be used to fry potatoes with, or to flavour any other dish.

Mushroom Sauce.—Pick out the stems, and skin the mushrooms and the stems. Cut them in small pieces, and wash them. Then put them in a saucepan, with rather more water than will cover them. Let them stew gently for about half an hour, or till they are soft. They will now have yielded a fine rich sauce. Stir in a little flour and butter kneaded together, and season with pepper and salt. This preparation may be eaten with potatoes, the same as meat; it also forms an excellent sauce to many dishes.

Melted Butter.—This must be made of fresh butter. Cut down the butter into small pieces, and put them into a small saucepan with cold water, in the proportion of an ounce of butter to a table-spoonful of water. Throw in flour from a dredger with the one hand, while with the other you turn the saucepan rapidly round, so as to cause the flour to mix without lumping. A small quantity of flour is sufficient. You now for the first time take the saucepan to the fire, and continue turning or shaking it till the butter is thoroughly melted. When it boils, it is ready; it should then have the consistency of rich cream. If it should oil in making, it may be partially recovered by putting a little cold water into it, and pouring it several times into and out of a basin. This sauce is the foundation of a number of other sauces, various additions being made to it for the sake of variety.

Onion Sauce.—Skin the onions, and boil in plenty of water. When soft, take them from the water, and chop them very fine. Melt butter as above, stir them in, and season with pepper and salt.

Candle Sauce for Plum-pudding.—Melt butter, as above directed, and stir into it a glass of sherry, half a glass of brandy or rum, a little sugar, grated lemon-peel, and nutmeg. Do not let it boil after the spirits have been added.

Lobster and Crab Sauce.—Melt the butter, as above directed. Pick out the meat of a boiled lobster or crab; chop it down very fine, and put it amongst the butter. Season with Cayenne pepper and salt. If the lobster be procured raw, with berries or spawn on the outside, these should be taken off previous to boiling, and being mashed in a little cold water, may be added to the sauce after the lobster is put in. By boiling a little, the whole will become a bright red. This forms an improvement on common lobster sauce.

Mint Sauce.—Take the leaves of fresh green mint. Wash them in boiling water, and after drying them, chop them very fine. Mix them with vinegar, and add a little sugar.

Beef Gravy.—A pound and a half of beef will make a pint of good gravy. Cut the beef in slices, or score it very deeply. Place in a saucepan, with a bit of butter to prevent it from sticking, and a sliced onion. Brown the meat gently, being careful not to let it burn. Cover closely, and let it stand beside the fire for about half an hour, to allow the gravy to run from the meat. Then put in about a pint of hot water, and let it boil slowly for an hour and a half, with some whole pepper. Boil along with it a piece of bread toasted hard and brown, which thickens the gravy, and adds to its richness. Season with salt, and strain through a hair-sieve.

To make a Stuffing.—Roast veal, fowls, turkey, and some other meats require stuffing. These stuffings have been alluded to in various receipts in the preceding pages, and may here be expressly defined. Take a quarter of a pound of the crumbs of stale white bread, a quarter of a pound of chopped beef-suet or marrow, as much chopped parsley as will lie on a table-spoon, about half a spoonful of chopped sweet marjoram, and a little grated lemon-peel, pepper, and salt. Mix all these thoroughly together with one beat egg and a little sweet-milk. This forms a species of dough in sufficient quantity for a small turkey or large fowl.

Raspberry Vinegar.—Pour a bottle of vinegar on two quarts of raspberries—the wild are the best—and let them stand covered for two days. Put through a sieve, pressing the fruit very gently, add to each imperial pint of the liquor one pound of

sugar, boil for seven minutes, take off the scum, and when cool, bottle for use.

Raspberry, Gooseberry, and other Jams.—Pick and clean the fruit well, and put on with an equal weight of good soft sugar and a very little water. Boil for twenty minutes, and pot when cool.

Pickles.

Red Cabbage.—Take off the outer leaves, and cut the cabbage into narrow straws. Sprinkle salt over them, and let them lie with a weight on them for two days. Wring the water out of them with a towel; put then in a jar as much boiling vinegar, seasoned with black and Jamaica pepper, ginger, and a few cloves, as will cover them. Let them stand for twelve hours covered up in a cool oven. *Onions.*—Skin as many small onions as are wanted, throw them into salt and water as they are skinned, and scald them in this. Let them stand in the brine all night. Next day, drain, and pour on them boiling vinegar, which has been seasoned with ginger, white pepper, and mace. *Beet-root* must be boiled till soft—taking care not to break or cut off the fibres, as by doing so the colour would be spoiled—cut in slices, and the boiling vinegar with the spices poured over it.

DRESSING VEGETABLES.

Potatoes.—Although nothing in the art of cookery appears more simple than the boiling of a potato, it is seldom that it is well done. In a dish of potatoes, select them as nearly as possible of one size, so that they may boil equally; if some are large, cut them in two. Wash the roots well, but do not break the skin in any way; fill the goblet half full with the potatoes, and cover them with cold water till it is an inch above them. Do not spare the salt. Do not boil too hurriedly, but rather let them simmer gently till soft, which can be determined by stabbing them with a fork. The moment they are ready, pour off the water, and set the pan by the side of the fire, with the lid off. The more quickly they are peeled and served, the better they are.

Fried Potatoes.—The French are adepts in frying potatoes: this is one of their ways of doing it. Clean and pare off the skin, then cut the potatoes into very thin slices, or shave them round and round as you would peel an apple. Dry the chips in a cloth, and fry in lard or oil. See that the grease boils; stir the potatoes till they are done to a light golden colour, then throw them on a sieve to drip, having sprinkled a little salt over them. Left potatoes may be sliced and treated in the same way—but they do not take so much time.

Cabbage.—Young cabbages are delicious boiled in water with a little salt. Wash them well before placing them in the pot, and if they are very large, cut them into halves or quarters. See that the water in the saucepan be boiling, and carefully remove any scum that may rise to the top. A tender young cabbage will be well enough boiled in about five-and-twenty minutes; an old cabbage will take double that time. All vegetables excepting peas should be boiled in a large quantity of water, to carry off any rankness of flavour.

Spinage should be carefully dealt with; it ought to be picked leaf by leaf, and must be frequently washed. It will take ten minutes to boil, and should be cooked in a large pan, where there is room for the leaves to float; plenty of salt should be put in the water, which must be boiling before the vegetables are placed in it. Drain the leaves on a sieve, and then squeeze the water out of it, chop it fine, and serve with a bit of butter.

Cauliflower.—This vegetable will take almost fifteen or twenty minutes to cook; the stocks should be placed for an hour in salt and water before being boiled. Boiling water with a good handful of salt in it must be used, and all the outside leaves must be stripped off. *Broccoli* is dressed in the same way as cauliflower.

Asparagus may be treated much in the same way as the preceding; the stalks will be ready in about twenty minutes or half an hour; and the moment they become tender, they should be lifted from the water, and served on buttered toast.

MISCELLANEOUS COOKERY.

LUNCHEON AND SUPPER DISHES.

To boil Tripe.—When tripe is purchased from the butcher in a raw state, it requires to be boiled a very long time, to be thoroughly soft and tender. The length of time will depend on the age of the animal from which it has been taken. Sometimes, for young tripe, six or seven hours will be sufficient, while old tripe will perhaps take ten or twelve. In all cases, boil, or rather simmer it very slowly, for quick boiling hardens it. It should be cut into moderately sized pieces for helping at table. When to be served plain, carry to table in a hash-dish, in some of the water with which it has been boiled, with boiled onions in it. A tasteful way of serving is to take it from its liquor after boiling, and stew it for about ten minutes in a saucepan with milk, which thicken with a little arrowroot, or flour and butter, and season with pepper and salt, immediately before dishing, as otherwise the salt is apt to curdle the milk. This makes a delicious and cheap dish.

To stew a Piece of Beef, or make Beef Bouilli.—Take a piece of beef—the brisket or rump, or any other piece that will become tender. Put a little butter in the bottom of the stewpan, and then putting in the meat, partially fry or brown it all over. Then take it out, and lay two or three skewers in the bottom of the pan; after which replace the meat, which will be prevented from sticking to the pan by means of the skewers. Next, put in as much water as will half cover the meat. Stew it slowly, with the pan closely covered, till done, with a few onions if required. Two hours are considered enough for a piece of six or eight pounds. When ready, take out the meat, and thicken the gravy with a little butter and flour. Cut down into handsome shapes a boiled carrot and turnip, and add them to the liquor; season with pepper, salt, and ketchup. Boil all together for a few minutes, and serve in a hash-dish.

To dress Cold Boiled Beef, or make Bubble and Squeak.—Cut the beef in slices of about the third of an inch in thickness. Fry till lightly browned and heated through. Then take them from the pan, and place them on a warm plate before the fire, to keep hot. Fry some cabbage which has been previously boiled and chopped; stir this about a short time in the pan, and season

with pepper and salt. Spread the cabbage in a dish, and place the slices of meat upon it; or heap the cabbage in the dish, placing the meat around it.

To broil Beefsteak.—A beefsteak is the most suitable of all kinds of meat for broiling, and is a dish universally relished. There are several parts of beef used for steaks, but in no case should it be from an animal too newly killed. The best steak is that cut from the rump—called in Scotland the *heuk-bone*—because it is the most juicy and well flavoured. Steaks should be cut in slices of from three-quarters of an inch to an inch in thickness, and into pieces of a convenient size for turning. Some persons dust the steaks with pepper before putting them to the fire, by which means the flavour of the pepper is infused through the mass. When placed on the gridiron, turn them very frequently; it is said, indeed, that the steaks should never be at rest, but this is carrying matters to an extremity. It is impossible to state any exact length of time to be employed in cooking a steak, for much depends on the tenderness and thickness of the meat, and the strength of the fire. The taste of the individual who is to eat the steak must also regulate the length of time; because, while some prefer steaks in a half-raw state, others wish them to be well done, that is, to have the colouring-matter of the blood fully coagulated. When cooked to the extent which is required, place the steak on a hot dish, and after rubbing it with a little good fresh butter, sprinkle it with a little fine salt. Beaf-steaks should be carried to table immediately on being dressed, and eaten forthwith, in order to be in perfection. Every moment they stand, they lose a portion of their flavour and juice. When sauce is required, either ketchup or oyster sauce may be used; if the latter, it should be made without flour or butter.

Sheep's Haggis.—This Scotch dish is not composed in all cases of exactly the same materials. Some put minced tripe in it, others put no tripe. The following is the most common, and, we believe, the best manner of making it: Procure the large stomach-bag of a sheep, also one of the smaller bags called the king's hood, together with the pluck, which is the lights, the liver, and the heart. The bags must be well washed first in cold water, then plunged in boiling water, and scraped. Great care must be taken of the large bag; let it lie and soak in cold water, with a little salt, all night. Wash also the pluck. You will now boil the small bag along with the pluck; in boiling, leave the windpipe attached, and let the end of it hang over the edge of the pot, so that impurities may pass freely out. Boil for an hour and a half, and take the whole from the pot. When cold, cut away the windpipe, and any bits of skin or gristle that seem improper. Grate the quarter of the liver—not using the remainder for the haggis—and mince the heart, lights, and small bag very fine, along with half a pound of beef-suet. Mix this mince with two small tea-cupfuls of oatmeal, previously well browned before the fire, black and Jamaica pepper, and salt; also add half a pint of the liquor in which the pluck was boiled, or beef gravy. Stir all together into a consistency. Then take the large bag, which has been thoroughly cleansed, and put the mince into it. Fill it only a little more than half full, in order to leave room for the meal and meat to expand. If crammed too full, it will burst in boiling. Sew up the bag with a needle and thread. The haggis is now complete. Put it into a pot with boiling water, and prick it occasionally with a large needle, as it swells, to allow the air to escape. If the bag appears thin, tie a cloth outside the skin. There should be a plate placed beneath, to prevent it sticking to the bottom of the pot. Boil for three hours. Serve on a dish without garnish or gravy, as the haggis is sufficiently rich in itself.

Lamb's Haggis.—This is a much more delicate dish, and less frequently made than a sheep's haggis. Procure the large bag, pluck, and fry of a lamb. The fry is composed of the small bowels, sweetbreads, and kernels. Prepare the bag, as in a sheep's haggis. Clean thoroughly the small bowels and other parts; parboil them, and chop them finely along with a quarter of a pound of suet. Mix with dried oatmeal, salt, and pepper, and sew the mixture in the bag. Boil in the same manner as a sheep's haggis.

To mince Cold Veal.—Cut the veal from the bones, and mince it in small square bits, and lay them aside. Then put the bones in a stewpan with a little warm water, to make a gravy. After stewing for a short time, take out the bones, and put in the bits of veal, with a small piece of lemon-peel, chopped very fine. When perfectly heated, thicken with a little flour and butter, and season with pepper and salt, and a little lemon-juice. Dish with small pieces of toasted bread, placed round the edge of the dish.

To dress a Lamb's Head and Pluck.—Lambs' heads are procured skinned. Take the head with the neck attached; split up the forehead, and take out the brains, which lay aside. Wash the head carefully, cleaning out the slime from the nose by rubbing it with salt, and take out the eyes. Put the head, thus cleaned, on to boil, along with the heart, and the lungs or lights. Let the whole boil an hour and a quarter; then take them out, and dry the head and neck with a cloth. Rub it over with an egg well beaten; strew crumbs of bread, pepper, and salt, over it; also stick small pieces of butter over it, and lay it in a dish before a clear fire, to be browned lightly. Mince the lungs and heart, and part of the liver, with some onion, parsley, pepper, salt, a little flour, and a table-spoonful of ketchup; mix all together, and add some of the liquor in which the head was boiled to form a gravy; let it simmer by the side of the fire for half an hour. Take the brains and beat them well with two eggs, two table-spoonfuls of flour, and a sprig of fine chopped parsley, also a little pepper and salt, and two or three table-spoonfuls of milk—the whole forming a batter. Have a frying-pan with a little lard or dripping, and fry the batter in small round cakes, which turn, and brown lightly on both sides. Cut the remainder of the liver in slices, and dust it with flour, and fry it. Now lay the head upon a dish; place the hash round it, and lay a slice of liver and a brain-cake alternately on the hash all round. This forms a handsome and a savoury dish, but requires great attention on the part of the cook, to have all the various parts hot and equally ready at the time of dishing.

To broil Mutton-chops.—Mutton-chops should be cut from the middle of the hind loin, and about the same thickness as steaks. They are

broiled in the same manner as steaks, and require equal attention. No butter is to be used on dishing, as the chop is sufficiently fat of itself. Sprinkle a little salt on it, and carry to the table immediately.

To fry Mutton-chops.—They require to be cut in the same manner as for broiling, and may be dressed according to the directions for steaks, &c. None of the grease which flows from the chops is to be used along with them, and the whole must be poured away before preparing the gravy.

Irish Stew.—Take a piece of loin or back-ribs of mutton, and cut it into chops. Put it in a stew-pan alternately with pared raw potatoes, sliced onions, pepper, salt, and a little water. Put this on to stew slowly for an hour, covered very close; and shake it occasionally, to prevent it from sticking to the bottom. Serve very hot. When properly made, and well seasoned, it is a most savoury dish.

Fried Liver.—Take a part of the portion called the 'tongue' of an ox's liver, parboil, cut into thin slices, and fry with sliced onions and fat bacon. Remove the liver and bacon, sprinkle a little flour in the pan, and brown it; pour on a little water, and bring to the boil as sauce. Lamb or sheep's liver should be cut in thin slices, but does not require to be parboiled.

PUDDINGS, PIES, AND TARTS.

Puddings.—Care should be taken, in making puddings, to have the suet and the eggs which are put into them perfectly fresh. If there be any doubt of the freshness of the eggs, break each individually in a teacup, for one bad egg will spoil the whole. The cloths used for puddings should be of tolerably fine linen. Let them be carefully washed after using, and laid aside in a dry state, ready for the next occasion. Before putting the pudding into the cloth, dip the cloth in boiling water, and after the water has run from it, spread it over a basin, and dredge it with flour. Every pudding should be boiled in plenty of water, so as to allow it room to move freely; and it must be kept constantly boiling: a pudding *cannot be too well boiled;* and it is certain there is much more danger of boiling it too short than too long a time. When you take the pudding from the pot, plunge it for a few seconds into a jar of cold water. This will chill the outside, and allow the cloth to be taken away without injuring the surface. The best way to dish a pudding is to place it with the cloth in a basin, then open the cloth, and lay the face of the dish upon the pudding; turn the whole upside down, lift off the basin, and remove the cloth.

Dumplings used formerly to be considered a very indigestible kind of food. By using the baking-powder, however, they can now be made light and wholesome. The paste is made by mixing a pound of flour with a heaped tea-spoonful of baking-powder, adding a quarter of a pound of lard or dripping, or half a pound of suet, making a paste of this with a small tea-cupful of water—hot, when suet is used—lining the dish with the paste, and inclosing with it the fruit, &c. and boiling in a cloth for two and a half to three hours. Rhubarb and gooseberries, blaeberries, or these mixed, and apples, prepared and sweetened as for tarts, and seasoned with nutmeg, answer very well. They are often eaten with a little nutmeg grated on them at table, and a bit of butter added; or they may be eaten with the addition of cream, or a sauce made of butter, a little water and milk, sugar, cinnamon, or nutmeg, to taste, and a glass of sherry wine, or half a glass of brandy or rum. No seasoning is needed when blaeberries are used, and cream is their best sauce.

Rice-pudding.—Take a pretty large cupful of rice, which pick and wash well in cold water. Boil it in water for about five minutes. Drain the water off, and put it on again with as much milk as you require. Boil till the rice is quite soft, stirring frequently, to prevent it from burning. When done, put it into a basin, and stir in a piece of butter, or some suet minced very fine. When cold, add four eggs, beaten, with a little ground cinnamon, grated nutmeg and lemon, and sweeten with sugar, and mix well together. It may be either boiled or baked, as directed for bread-pudding. The above composition may be enriched by using more eggs and less rice, also by adding currants, spirits, and candied orange-peel.

Custard-pudding.—Take four eggs, and beat them well with two table-spoonfuls of flour and a little cold milk. Season this with sugar, ground cinnamon, grated lemon-peel, and pour on a pint of boiling milk, stirring all the time. It may be either baked or boiled. By using more eggs, the flour may be omitted.

Bread-and-butter Pudding.—Cut several slices of bread rather thin; butter them on one side; put a layer of them in a pudding-pan or dish, and a layer of currants above; then another layer of bread; and so on till the dish is full. Beat four eggs, with a little ground cinnamon and nutmeg, also some sugar. Add milk to this, till there is sufficient to fill up the dish. Then pour it over the bread, and allow it to stand for a time to soak. It will now be ready for either baking or boiling, as directed for bread-puddings.

Tapioca-pudding—Sago-pudding.—Take a quart of milk, and put to it six table-spoonfuls of tapioca. Place it on the fire till it boil; then sweeten to taste, and let it simmer for a quarter of an hour. Stir frequently, and be careful that it does not burn. Then pour it into a basin, and stir into it a little fresh butter, and three eggs well beaten; you may now pour it into a buttered pudding-dish, and bake for about an hour; or, after adding another egg, boil it in a basin or mould for an hour and a half. *Sago-pudding* may be made in the same manner.

Pancakes.—Take three eggs, beat up with a little pounded loaf-sugar, add a small table-spoonful of flour for each egg and rub till smooth. Put in as much milk as will make the whole of the consistency of cream; add a little cinnamon, or a drop or two of lemon. Put a bit of butter or dripping in the frying-pan; make hot, and pour in half a tea-cupful of the batter, so that it cover very thinly the bottom of the pan; and brown lightly, then toss and turn to do the other side. Slip a knife under the edge all round, and roll up, fold into three, and lay on the dish. Sprinkle a little pounded loaf-sugar, and eat very hot with raspberry vinegar. When put out in this way very thin, it is unnecessary to turn them.

Plain Rice-pudding.—Take a tea-cupful of rice, wash clean, put in a dish with three breakfast-cupfuls of milk, two tea-spoonfuls of sugar, a little

salt, and a little ground cinnamon. Set in a very cool oven, or on the girdle, and let the whole simmer for three hours. Eat plain, or with raspberry jam and a little raspberry vinegar, or gooseberry jam, and cream or milk.

Semolina or Manna-croup Pudding.—Take half a pound of semolina, and put it in a pan with an imperial pint of milk, and the same of water, a bit of butter, a very little salt, and a table-spoonful of sugar. Keep stirring, and boil for ten minutes; season with five drops of essence of almond, and twenty drops essence of lemon. Serve in a dish with bits of jam round it, or in a shape, and eat warm or cold, as above, with jam, cream, &c.

Rice-shape.—Take a pound of whole rice, wash well, and put in a pan with a quart of milk, the same of water, a bit of butter, a little salt, and six or eight pieces of lump-sugar; and simmer very slowly with closed cover, without touching, for three hours. Flavour as above, when ready, with essences of almonds and lemon; press into a shape, and eat cold with jam, as above, and cream.

Plum-pudding.—A plum-pudding may be made either rich or plain, according to the quantity of fruit and spices put into it. The following is the direction for making what would be considered in England a *good Christmas-pudding:* Take a pound of good raisins, and stone them; a pound of currants, which wash, pick, and dry; a pound of rich beef-suet minced, and a pound of stale bread-crumbs or pounded biscuit, and half a pound of flour. Mix the bread, flour, and suet in a pan. Beat six eggs in a basin, and add to them about half a pint of sweet-milk. Pour this egg and milk into the pan with the suet and flour, and beat it well with a flat wooden spoon for some time. Then stir in the currants and raisins, mixing well as you proceed; mix in also a quarter of a pound of candied orange and lemon peel cut in thin small pieces, an ounce of powdered cinnamon, half an ounce of powdered ginger, a nutmeg grated, and a little salt. Next add a glass of rum or brandy. The pudding is now made, and ready to be either baked or boiled, according to taste, but to boil it is best. If to be baked, butter your tin or basin, and put the pudding into it, and bake in an oven for an hour and a half, or nearly two hours. If to be boiled, pour it into a cloth; tie the cloth, allowing a little room to swell, if made of bread, and boil for six hours. Serve with caudle-sauce.

Currant-pudding.—An excellent family pudding may be made of the following ingredients: A pound of minced suet, a pound of bread-crumbs or flour, three-quarters of a pound of currants, washed and picked, a little powdered cinnamon and grated nutmeg, and a very little salt. Beat two eggs, and add as much milk to them as will wet the whole. Mix all together, tie in a cloth, as previously directed, and boil for three hours. Serve with caudle or any simple sweet sauce.

Bread-pudding.—Boil as much milk as will be sufficient for the pudding you want. When it begins to boil or rise in the pan, pour it upon crumbled-down stale bread in a basin. The quantity of bread should be as much as will thicken the milk to a stiff consistency. Cover it up for ten or fifteen minutes, to allow the bread to swell. Then beat or mash it up to make a fine pulp, stirring in a small piece of butter. Beat three or four eggs, a tea-spoonful of ground cinnamon, a little grated lemon-peel, and sugar according to taste. Stir this among the pudding. A little brandy or rum may be added; also a few currants, if required. The pudding may be either boiled or baked. If to be boiled, put it in a well-buttered pudding-shape or basin, with a buttered paper over it, and also a cloth over all: boil for an hour. If to be baked, put it into a buttered baking-dish, and bake in an oven for half an hour.

Pies are of two kinds—meat-pies and fruit-pies or tarts. Both are composed partly of paste, and therefore a knowledge of making pastry is indispensable to the economical housewife and cook. For this operation, the hands should be washed very clean, and care taken to have the board for working upon smooth, clean, and dry.

Under the head of 'Beefsteak Pie,' directions are given for making a light and very wholesome paste, which also answers quite well for tarts, but it can be made a little richer if wished.

On taking pies from the oven, and while quite hot, the crust may be glazed with white of egg and water beat together, or sugar and water laid on with a brush; or a little pounded sugar can be sprinkled on tarts before serving. Cream may be used with all the tarts.

Icing for Tarts.—After tarts are baked, they are sometimes iced on the top, to improve their appearance. The icing is done thus: Take the white of an egg, and heat it till it is a froth. Spread some of this with a brush or feather on the top or cover of the tart, and then dredge white-sifted sugar upon it. Return the tart to the oven for about ten minutes.

Rhubarb Tart.—Take as much rhubarb as wanted—Victoria is the best kind—skin and cut up into small pieces, fill the pie-dish, and add sugar, a very little water, and a little ground ginger and cinnamon. Put an old teacup in the middle of the pie-dish, as this prevents the juice boiling over. Cover and bake for about three-quarters of an hour.

Apple Pie is made with the same seasonings, or a little pounded cloves, or grated lemon-peel.

Gooseberry Tart is made in the same way, the gooseberries being cleaned, and the heads and stems picked off. When the gooseberries are young, no spices are required. Rhubarb and gooseberries make an excellent mixture.

Raspberry, Cranberry, and other Tarts are made in a similar way, but require no seasonings. All require to be picked and wiped, and to have sufficient sugar to sweeten them. Red, black, and white currants, plums, &c. may all be used in the same way. The wild raspberries are the highest flavoured.

Stewed Rhubarb, Apples, Gooseberries, &c. are prepared in the same way as for tarts, and are stewed with sugar, a very little water, ground cinnamon and ginger. Eat cold with cream.

Mince Pie.—Mince pie is a composition of meat, fruit, various spices and seasonings, and also spirits. The following is a properly proportioned mixture: Mince a pound of beef-suet and a pound of roast-beef, or dressed fresh bullock's tongue; also a pound of apples pared and cored, minced separately from the suet and meat; a pound of

currants washed and picked, a pound of stoned and chopped raisins, an ounce of ground cinnamon, half an ounce of ground ginger, an ounce of orange and an ounce of lemon peel, and a little salt; half a pound of raw sugar, one nutmeg grated, two glasses of brandy, and two of sherry. Mix all these ingredients together, and lay the bottom of your dish or small tin pans with paste; fill these with the mince, and then cover them with puff-paste. Put in the oven, and bake for half an hour. If the whole of the mixture be not used, what remains over will keep for a long time if placed in a close jar. Some persons do not put any meat in their mince pies.

Open Tarts.—These are tarts without covers, made in flat dishes. Cover the bottom of the dish with a paste, and cut a strip of it and lay round the edge of the dish. Fill the centre with any jam or preserved fruit. Decorate the top of the jam with narrow bars of paste crossed all over, or stamped leaves. Bake half an hour. With any paste left over, a very good tart may be made by spreading with fine treacle, dusting this with ground cinnamon, doubling up like a puff, and baking for a few minutes in the oven. Eat with cream or milk and raspberry vinegar.

BILLS OF FARE FOR ALL CLASSES.

Many housewives, when left to their own resources, experience much difficulty in planning a dinner. To those who have not the assistance of a professed cook, but who wish to unite taste with economy in the management of their dinner-table, the following hints may be acceptable.

The first thing to take into account is the season of the year, and to know what fishes, meats, vegetables, and fruits are in season. Food is always best when it has been allowed to arrive at what may be called its natural time of maturity. 'House-lamb' is poor eating in February, compared to a grass-fed joint of the same animal in July or August; and strawberries or green peas have a finer flavour when they are grown in the open air than when they are forced in a hot-house, or brought from Algiers. To affect such 'delicacies,' as they are wrongly called, is both extravagant and in bad taste.

The following is a sketch of a few dinners suitable for the early period of the year; the first may be called a Christmas dinner.

1. Mock-turtle soup, and clear ox-tail soup, removed with a cod's head and shoulders, and a dish of stewed eels, to be followed with a boiled turkey and a roast saddle of mutton. Plum-pudding, tart of apricot jam, and a few other sweets. Potatoes and Brussels sprouts are suitable vegetables.

2. A piece of boiled beef and a roast goose may vary the dinner, if it be repeated. Greens ought to be served with the beef, as also a few slices of carrot and turnip.

3. Leek soup is an excellent soup for use in January and February, as also hare soup.

We do not think it necessary to indicate a *menu* for 'stylish' dinners, but the following hints for setting out the dinner-table for a succession of seven days, during various seasons, will be found useful.

January and February. *First day*—Leek soup, baked cod with oysters stewed in beef gravy, leg of mutton roasted, potatoes in their jackets, broccoli, apple dumpling, cheese. *Second day*—Remains of cod-fish curried, a dish of stewed steak, cold mutton, rolly-poly pudding. *Third day*—Hare soup, boiled gigot of mutton with turnips and potatoes, curried rabbit with rice, apple tart, cheese. *Fourth day*—Boiled haddocks with melted butter, roast goose with apple sauce, mashed potatoes, macaroni pudding. *Fifth day*—Roast of beef-ribs with horse-radish, potatoes and Brussels sprouts, pancakes, fish if deemed necessary. (Some families have always a service of fish on Fridays.) *Sixth day*—Kidney soup, fried whitings, a roast fowl with toasted ham, bread-and-butter pudding. *Seventh day*—Pea soup made from bones of beef and parings of ham, a bit of turbot, beefsteak pie, apple fritters, cheese.

April and May. *First day*—Stewed veal with vegetables, beefsteak pie, rhubarb tart. *Second day*—Brown soup, boiled mackerel, a joint of lamb, batter pudding. *Third day*—Scotch broth, boiled neck of mutton, potatoes and young cabbage, macaroni pudding. *Fourth day*—Brown soup, roast gigot of mutton with a dish of sea-kale, rhubarb dumpling. *Fifth day*—Boiled salmon, roast lamb, cheese. *Sixth day*—Spring soup, baked mackerel, curried fowl, and custard pudding. *Seventh day*—Dressed lamb's head, a dish of stewed steak, gooseberry tart.

Summer dinners. *First day*—Cold lamb and salad, curried fowl, fruit pudding. *Second day*—Vegetable soup with rice, made from a piece of lean mutton, boiled mackerel, mutton cutlets, cold tart. *Third day*—Ox-tail soup, curried soles, roast lamb and cabbage, gooseberry tart. *Fourth day*—Salmon trout cold, cold veal and ham pie, cold fruit tart, curds and cream. *Fifth day*—Green pea soup, roast leg of mutton with cabbage and new potatoes, pancakes. *Sixth day*—Cold boiled beef, boiled gooseberry dumpling, cheese with salad. *Seventh day*—Fore-quarter of lamb roasted with mashed turnips, boiled fowl, bread pudding.

Miscellaneous dinners. *First day*—Rice soup, fresh herrings boiled in salt water, roast fillet of veal, plum tart, cheese and salad. *Second day*—Vegetable marrow soup, fried soles and melted butter, lamb cutlets and French beans, baked raspberry pudding. *Third day*—Salmon pudding, macaroni stewed in beef gravy, and baked with grated cheese, stewed beef with new cabbage, baked raspberry pudding. *Fourth day*—Ox-tail soup with cut carrot, baked soles, roast fowl garnished with toasted ham, baked bread pudding, cheese and salad. *Fifth day* (A fish dinner)—Oyster soup, filleted haddocks fried with bread-crumbs, crimped skate, salmon dumpling, baked cod-fish, whitebait, stewed eels, crab pie, crappit heads, fish sauce, curried whitings. *Sixth day*—Julienne soup, fried flounders, roast leg of mutton with onion sauce, boiled fowl, cauliflower, apple dumpling, cheese and salad. *Seventh day*—cold salmon in its own sauce, beefsteak pie, cold roast fowl, tongue, a dressed salad with crayfish.

These bills of fare are only given as examples, and none of them need be rigidly adhered to, as the joint of one bill of fare may follow the soup of another, and so on, till any number of days are provided for. The following is an example of what may be done in this way. Take the rice soup of the first day in Miscellaneous Dinners, the fried soles of the second day, the stewed macaroni of the third day, the roast fowl of the fourth day, and the apple dumpling of the sixth day, and you have an excellent bill of fare. One good dinner ought to serve as a foundation for the next that is to follow; as, for instance, a cod that is baked for one day, may be made useful on the next day, as what remains of it may be curried, and so form a palatable dish. The water used for boiling a ham or tongue, or gigot of mutton, may be used as

stock for pea soup or Scotch broth. Cold plum-pudding can be fried, and large roasts which are not all used when first prepared, can be sent to table again in many different forms.

RECEIPTS FOR COLD-MEAT COOKERY.

Meat is never so palatable as when it is fresh cooked, and it is well so to order meals as to have as little cold meat to use as possible. But in so far as the use of it cannot be altogether avoided, the economical housewife should know how to turn it to the greatest advantage.

Cold beef may be re-cooked in many ways. Here is one way of making up a *beef ragout*, which is in season at all times. Take the flesh that remains of a roast of beef and cut it in good slices; place in a stewpan, and cover with a little boiling water; add half a dozen of sliced onions, and spice with pepper, salt, and ketchup to taste; boil for an hour and a half, and then serve with pickles warmed in a little of the gravy.

Bubble and Squeak.—Cut a few thin slices from a piece of cold boiled beef, and fry them well in a little butter. Also prepare some nice cabbage or savoy, according to the season, to dish along with the meat; they ought first to be well boiled; then after being drained of all moisture, they should be chopped up, and fried with butter; the seasoning being finely sliced onions with pepper and salt. This dish can be quickly made ready, half an hour being ample time for its preparation.

Broiled Beef with Oyster Sauce.—Stew the oysters in a little beef gravy for five or six minutes after they begin to simmer, adding a little spice. Broil some slices of beef on a very clean gridiron over a clear fire, place in a corner-dish, and serve with the oyster sauce poured over. Nicely browned mashed potatoes make a capital accompaniment.

Broiled Beef and Mushrooms may be prepared much in the same way as directed in the preceding receipt for broiled beef and oyster sauce. It is worth noting that meat which has already been roasted or boiled does not take long to cook; of course, when it is cooked along with vegetables, the turning of each must be carefully studied: all the re-cooking that cold beef and mutton usually require is to be allowed to become thoroughly hot, and have time to absorb the flavour of the spices with which they may be prepared.

Cold Roast Beef makes an excellent luncheon with warm potatoes and a pickled walnut.

Broiled Beef Bones served with mashed potatoes are an excellent dish. Broil them till thoroughly hot, and during the process sprinkle with a seasoning of Cayenne pepper and table-salt.

Baked Beef.—Cold roast meat can be utilised by being baked. It forms a very nice dish with vegetables, the whole being set in a crust of mashed potatoes. Cut the beef into slices, each with a little fat if possible, and put in with layers of vegetables, onions, carrots, and turnips, and a little gravy to which half a tea-cupful of sweet ale has been added; cover with crust of potatoes: it will bake in about thirty-five minutes.

Curried Mutton makes a nice palatable dish. Prepare the curry in a stewpan with a few onions and a slice or two of butter (say a quarter of a pound); the onions should first be fried in the butter; and the curry-powder, about a table-spoonful, mixed with a little flour and water, ought then to be added. Slice the meat, and put it to the curry, and then stew the whole gently for about half an hour, dish, with a border of boiled rice.

Mutton Cutlets may be prepared from the remains of cold neck or boiled mutton; dip them in whisked egg, and sprinkle with good rough oatmeal or pounded biscuit, and fry till nice and brown. Serve with tomato sauce.

Cold Mutton done as Sausages.—Chop up some cold mutton very finely with a very little beef-suet, mix the whole well together with bread-crumbs or rice, and a good seasoning of pepper and salt, roll into sausages, with a thin paste, and then fry till nicely browned: twenty minutes will cook them.

Cold Mutton may be cut up into small pieces, and stewed in a nice gravy of flour thickened with brown soup; season to taste, with ketchup or onion soup.

Cold Mutton Broiled and served with tomato sauce is a good dish. Cut a few slices of cold mutton, and broil on a clean gridiron; serve hot with warm sauce poured over.

Hashed Duck with Peas.—Cold duck may be jointed and re-cooked into a palatable hash, served with pieces of ham and green peas. Put a little butter in a stewpan, then add the duck, cut into pieces, with a few slices of lean bacon; add a bunch of spring onions cut small; season with cloves, salt, and Cayenne; it will cook in about an hour. Serve in the middle of a deep dish with the peas round it, and the bits of lean bacon separate. Other cold fowls may be treated much in the same way.

A Fish Pie.—The remains of cold cod or other fish may be nicely recooked. Take all the flesh from the bones, and place it in a pie-dish; pour over it some melted butter and a few stewed oysters. Cover with a paste of mashed potatoes, and brown nicely in the oven. When the potatoes are nicely browned, the pie is ready.

Curried Cod.—Pick off the flesh of the fish from the bones, and fry for a little time among butter and onions till nice and brown. Mix a tea-spoonful of curry-powder with some flour and water, as also a little cream if approved, and let the whole simmer in a saucepan for about an hour, when it will be ready to serve.

Australian Cooked Beef and Mutton.—A tolerably successful attempt has been made, in the face of many prejudices, to introduce into our *cuisine* quantities of 'cooked' beef and mutton from Australia and New Zealand, packed in tins of various weights convenient for sale. This meat, which is quite wholesome and good for food, may be purchased free from bone, at an average of 7½d. a pound, a price that contrasts very favourably with the fresh meat which costs us, with its bone and refuse, about 1s. 6d. a pound-weight. A large number of dishes can be prepared from this ready cooked beef; and it is thought by those best able to judge, that it will come to be largely used, not only by cottagers and in public institutions, but by wealthy families as well. Directions for making it into soups, hashes, stews, curries, and pies, are usually given along with each tin.

COTTAGE COOKERY.

In Scotland, the dish almost universally used for breakfast by the working-classes and for children

is oatmeal *porridge*, the oatmeal being rougher in the grain than is generally used in England. The fault commonly committed in making this excellent and wholesome article of food is in not boiling it sufficiently. Three-quarters of an hour's boiling is required to break down the meal, and render it properly digestible. Where the water is 'hard,' a very small bit of washing-soda accelerates the process; but this requires to be cautiously used. Churn or sweet milk, or a mixture of the two, is used along with the porridge. Among the middle classes, the plate of porridge is often followed by a cup of coffee, which is calculated to correct the sluggishness which some persons feel after taking porridge.

Coffee to breakfast is now the article most commonly used by the middle classes in this country. It is preferable to tea when the latter is taken in the evening. Strong tea twice daily, for nervous persons especially, amounts to a species of dissipation, and produces upon some very unpleasant effects. The stimulus from taking coffee is more gentle and diffused, and is quite as long continued. To prepare really good coffee, is found by many housewives to be rather a difficult matter, and yet it is very easy, if a few simple directions are attended to. The object in view is to get the coffee to impart to the water poured on it the slightly bitter and aromatic principles which it contains, and to lose none of these. This is best done by pouring on the coffee in the coffee-pot boiling water, accurately closing the cover of the coffee-pot, and fixing a nozzle on its spout, and then placing the pot on the fire, and just allowing the water to boil. The moment steam appears, the coffee is made, and the pot must be taken off the fire. Coffee made in this way has the one disadvantage, that it is not so clear as could be wished. To obviate this defect, the white of an egg or isinglass is sometimes used, but this is troublesome; and a coffee-pot, with a good percolator, though a little more expensive at first, is on the whole, the best arrangement. A fourth of foreign chicory imparts body and improves the quality of the coffee; and if these have not been got within a day or two after being roasted, they should be heated together over the fire in an iron pot before being used. Mr Soyer made the important observation, that coffee thus heated, and tea heated in the teapot for ten minutes before infusing, are both in consequence made to part with their aromatic properties more readily. For breakfast, one-third of boiled milk should be used with the coffee, the latter of course being made proportionately strong; or cream alone, or with the milk, may be used when the coffee is wished richer. In infusing *Tea*, besides slightly heating it as mentioned, most housewives are aware that where the water is hard, a small quantity of carbonate of soda assists the process.

As relishes to the tea or coffee, the best are good salt, red, kippered, or Nova Scotia herrings, a Finnan haddock, an egg, a bit of fried smoked bacon, tongue, &c. In June and the two or three following months, one of the great annual treats of this kind enjoyed by the population in the towns in the west of Scotland is the delicious Loch Fyne herrings, very slightly salted. Salt herrings generally require to be steeped in cold water for a night, and are then used boiled, or 'reisted'—that is, hung up and dried, and done on the gridiron. Among the most delicate of breakfast-dishes, when in season, are the 'rizzard' whitings or small haddocks. Rizzaring a haddock means simply cleaning it, slightly salting, and hanging it up to dry for a day or two.

Dinner in this country is generally considered the most important meal. In England, the workman must have for it his bit of roast-meat or stew, with pudding, pie, or dumpling; while in Scotland he rarely tastes roasts or dumplings, and is content for the most part with 'broth and meat.' Perhaps each could, for the improvement of this meal, with advantage borrow some hints from the other. The Englishman would find it advantageous to have introduced at his table the wholesome vegetable soups so largely used in Scotland, while the Scotchman would experience both variety and satisfaction from having more of the savoury dishes in which his English neighbour delights.

The Scotch working-man almost invariably takes his soup first, and eats afterwards a portion of the meat with which it has been made. When it is wished not to have the qualities of the meat too much diffused in the soup, it is sometimes taken out for an hour or so. Where mutton is used, instead of returning it to the soup, it may be sprinkled with a little pepper and salt, slightly browned before the fire, and served with onion sauce, which greatly improves the qualities of the mutton. As has been already mentioned, when it is intended that the meat should be eaten without the soup, instead of using cold water, it should at once be immersed in boiling water, so as to coagulate the outer layer of albumen, and retain its juices; and then boil with closed cover very gently whatever time may be required, a quarter of an hour being allowed for each pound of meat. The water in which the meat has been boiled can be used next day as a stock for making broth or soup.

Killing a pig gives the means, to a cottager's or workman's family, of having several nice luxuries, such as the blood and white puddings, the dressed 'pluck,' the salted 'pig's cheek,' eaten with greens, the feet salted slightly, and made into delicate soup with vegetables, tasty pork sausages, rich pork and mince pie, and delicious spare-rib roasted. The suet should be carefully 'rinded' by melting off the lard in a pot placed in boiling water, adding a little salt, and then should be put in pots covered with bladder, or in bladders, to exclude the air. It may be used, when required for pie-crust, &c.

The Pot au Feu is an adjunct of nearly every house in France, and in some other foreign countries as well; it is a receptacle for all sorts of scraps, which are kept constantly simmering by the side of the fire; and such pieces of meat or fragments of vegetables as cannot otherwise be used, are thrown into the pot, in order to contribute to the soup, which by this means can always be obtained.

MEDICINE—SURGERY.

THE belief that some human beings attain the power of curing the bodily ailments of their fellow-creatures, is one of the highest antiquity. In ancient times, the practice of medicine was in the hands of the priests, who were supposed to be capable of controlling the operations of nature, in consequence of their presumed communion with the world of spirits. As knowledge advanced, medicine was separated from religion, and a new profession arose—that of the art of medicine, or the curing of the sick. This art, in course of time, was divided into two, Medicine and Surgery; and in our day we find men devoting their attention almost exclusively to one or the other branch. But it is important to observe, at the outset, that there is no clear line of demarcation between the two. No surgeon can be truly great in his department of practice who is not familiar with the art of medicine, and the converse proposition also holds good. We have this fact well illustrated by the familiar example of the general practitioner, who is a man engaged daily in the treatment of cases which fall into the domain of the physician, but who also practises surgery when he meets with wounds, fractures, dislocations, or other injuries. At one time, the practice of medicine or surgery was hidden in mystery. The treatment of certain surgical affections, for example, was kept a profound secret, which was handed down in families from father to son. But medicine and surgery are now liberal arts. No member of the profession deals in secret methods of investigation or treatment; but, on the contrary, should he discover any better mode of relieving suffering or detecting disease, he is bound at once to announce it for the good of all. The profession is also more liberal as regards the public than it was at one time. It does not encourage a love of the marvellous; it does not pretend to work almost miraculous cures. It announces to all that the art of healing is founded on a knowledge of the laws of health, and on a knowledge of the precise action on the body of substances called medicines. It is the object of this article to give a sketch of medicine and surgery such as will be understood by an intelligent reader. It is not intended to supplant the doctor, but to give, if possible, correct notions regarding his work, and to indicate what should be done in minor ailments, or in cases of sudden illness or accidents.

Before commencing the subject, however, it may be well to state briefly a few rules which ought, as far as possible, to guide people in their relations with medical men.

1. In all cases of illness, except well-known slight complaints, the doctor should be called in as soon as possible. Delay is often dangerous to life, and, at all events, will postpone recovery.

2. After a doctor has been called on to take charge of a case, his orders should be rigidly carried out. Frequently, the purpose of these orders may not be understood, but still they should be attended to. Nothing is more annoying to a medical man, on his second visit, than to find that what he recommended for the good of the patient has been set aside or overlooked; and his annoyance is usually aggravated by finding his patient worse than he expected.

3. While a doctor has charge of a case, no other medical man should be consulted without the consent of the doctor first in attendance. This is a rule often broken. While it is unjust to the patient to interfere with his treatment, it may be the cause of heart-burnings and misunderstandings between the medical men, who may have been friends. If the friends of the patient have lost confidence in the doctor, he should be asked to meet with another in consultation. To do this requires moral courage, but it is right.

4. When a doctor is consulted, he should not always be expected to write a prescription. Many people imagine that the only way of treating a disease is to give medicines, and they are, consequently, disappointed if the doctor sends them away without a nauseous mixture or a potent pill. This idea has indirectly led to much almost unconscious quackery on the part of some members of the profession, for which the public has itself to blame. A change of diet, or of scene, or of work, or abstinence from a luxury, or giving up a certain habit, may be all the doctor recommends; and yet, by following his advice, the disease may be cured.

MEDICINE.

Before giving a general description of the diseases which are treated by the physician, it is necessary to understand what we mean by health and disease. Health is the condition of the body when all the functions of the various organs are perfectly and harmoniously performed. Disease is any deviation from this condition. Disordered function almost always depends on changes in the structure of the part. Disease is not an entity, a something introduced from without; it is merely a word expressing a state in which one or more of the functions of the body are disturbed. This is true even in those cases in which the symptoms of fever or ague may be the result of the introduction into the body of a poison emanating from decomposing animal or vegetable matter. The poison is carried by the blood to the tissues and organs, and so affects these that their functions are disturbed. This disturbance constitutes the disease. At one time, disease was considered as something entirely foreign to the body, introduced from without, and therefore to be expelled as soon as possible; and the means used for the expulsion of the enemy were often so vigorous as to leave the citadel in ruins. With

more enlightened views, the scientific physician now regards disease as a disturbance of healthy functions; and he tries to conduct the case towards recovery by removing causes of disturbance, not only by the skilful use of medicinal agents which have been proved to have definite actions on the body, but also by careful dieting and nursing.

Diseases may bè grouped in various ways, but we will adopt a classification founded on the physiological systems. All diseases will not be referred to, but only those common amongst us, and which may be recognised and treated in at least their earlier stages by an unprofessional person.

I. DISEASES AFFECTING THE DIGESTIVE SYSTEM.

1. *The Tongue.*—In individuals who have suffered from long-continued disorder of the digestive organs, the tongue is often ulcerated superficially, and is raw and tender to touch. Change of diet, the extraction of decayed teeth, and small doses of Gregory's powder, will usually be followed by recovery. If the symptoms remain after this treatment, medical advice must be taken. Occasionally, the tongue is covered, near its tip, with rugged cracks, which are exquisitely painful. The application of borax and honey will give relief. The practice of smoking with short clay pipes produces irritation of the textures of the tongue, which may lead to a form of cancer. The presence of a hard, painful swelling, frequently with salivation, renders medical advice necessary without loss of time.

2. *The Mouth.*—Inflammation of the lining membrane of the mouth is not uncommon in children. The usual appearance is that of small white spots, or patches, scattered over the tongue and cheeks, constituting what is known by mothers as the *thrush*. These spots are readily removed by the application of a lotion, consisting of 120 grains of borax dissolved in 1 ounce of water. The mouth of the child and the nipple of the mother should be wiped after suckling. The disease known as the *mumps* is an inflammation of the parotid gland, the largest of the salivary glands. There is fever, and a hard swelling from beneath the ear to the chin. Usually, this disease passes off in a few days, without any treatment except a dose of laxative medicine, and the application of hot fomentations or flannel to the throat.

3. *The Throat.*—The most common affection of the throat is quinsy, which is an inflammation of the tonsils, two glands, one being placed in a recess on each side of the opening of the throat, Quinsy is caused, usually, by cold. There is fever. pain in the throat, and difficulty in swallowing and in speech. The tongue is foul. The throat, when examined internally, is red, and the swollen tonsil or tonsils may be seen. The inflammation may subside in a few days, or it may pass into suppuration—that is, matter or pus may form in the gland, and ultimately escape. The treatment is the application of hot poultices to the throat, the inhalation of steam from a basin of warm water, a dose or two of a saline purgative (No. 1),* and a milk-diet. If the tonsil suppurates, the abscess may require to be opened. This can only be done by a medical man.

4. *The Stomach.*—When we consider the great variety in the articles of food consumed, and the heedlessness with which many eat indigestible substances, and drink fluids, such as raw spirits, which affect the coats of the stomach, it is not surprising that this organ should be frequently in a diseased state. The mucous lining of the stomach is the part commonly affected. Acute inflammation of this organ is usually the result of the swallowing of hot or irritating liquids, such as boiling water or acids, and is, consequently, rare; but chronic forms of inflammation, giving rise to what is called *dyspepsia*, are extremely common. There are at least two distinct kinds of this disease—namely, that in which there is an excessive secretion of gastric juice, the fluid which digests the food, and that in which there is a deficient supply of this fluid. The general symptoms are similar in both cases—namely, a feeling of uneasiness after meals, referable to the pit of the stomach; flatulence, from the accumulation of gas in the stomach or bowel; costiveness; furred tongue, foul breath; palpitation, headache, irritability of temper, and tendency to melancholy. When there is an excessive secretion of fluid, the sensation at the stomach is hot and burning, and is attended by eructations of quantities of acid or watery fluid, called familiarly the *water-brash.* In the other form of the disease, the sensation is that of a heavy weight at the stomach, often oppressing the breathing. No fluid is brought up. Dyspepsia is a disease difficult to cure, chiefly because it is impossible to give the stomach entire rest in ordinary circumstances. The chief point to attend to is diet. The plainest food should be taken. Where there is much irritability, milk mixed with lime-water is useful. Fish or fowl is preferable to meat. Bread consumed should be old or toasted. As a rule, vegetables do harm. All fruit, pastry, preserves, cheese, beer, and spirits should be forbidden. With regard to medicines, much will depend on symptoms. To relieve that form attended by water-brash, bismuth and magnesia are useful (No. 2). The other form of dyspepsia may be beneficially treated by mineral acids (No. 3), which increase the gastric secretion. The bowels should be kept regular. The patient should take exercise in the open air as much as he can bear, and, as far as possible, he should be freed from anxiety and worry.

5. *The Intestines.*—*Inflammation* of the bowels is a very serious disease. It is characterised by shiverings, hot skin, and a quick pulse. There is pain around the navel, which is increased on pressure, and the sufferer lies on his back with the knees drawn up. There is obstinate constipation, and frequently nausea and vomiting. Such a case demands medical skill, which should be summoned without delay. In the meantime, relief may be obtained by hot fomentations, or large poultices placed over the abdomen. *Dysentery* is a specific inflammation of the mucous lining of the lower part of the bowel. True acute dysentery is not common in the British Islands. The symptoms are similar to those of severe diarrhœa, but the evacuations are frequently bloody, and contain sloughs or shreds of mucous membrane. The treatment now adopted in India is to administer 30 to 60 grains of ipecacuanha powder. The general strength must be supported by milk, raw eggs, soups, &c. Ordinary *diarrhœa*, or looseness of the bowels, may be

* See prescriptions at end of this article.

caused by eating unripe fruit, indigestible food —such as duck, or veal, or salmon—by drinking impure water, by mental excitement, or by cold or damp. The symptoms are well known. If caused by any irritating food or fruit, a dose of castor-oil, along with 8 or 10 drops of laudanum, should be given. If due to other causes, astringents, such as chalk mixture (No. 4), are serviceable. The irritation of having a constant desire to go to stool, with pain, called tenesmus, may be relieved by a warm hip-bath. The diet should be nutritious and non-stimulating—such as arrowroot, or rice and milk, or white fish. Where there is severe pain, the individual may take with benefit a little cold brandy and water. *Pain* in the bowels, or *colic*, is usually due to flatulence. It may be distinguished from inflammatory pain by the fact of being relieved by pressure, while there is no fever or quickness of the pulse. As a rule, the pain is quickly removed by hot brandy and water, followed soon after by a dose of castor-oil. *Constipation* is more a symptom than a disease, and as it may be caused in many different ways, it is difficult to treat. Medical advice is necessary; but it may be laid down as a general rule, that the habit of taking purgatives daily is injurious. The patient should try various kinds of diet, indulge in outdoor exercise, and take as little medicine as possible. Occasionally, the bowels become *obstructed*, so as to prevent the passage of fæcal matter. This is a disorder often fatal. It requires the best advice; and all we can do here is to indicate the earlier symptoms. These are vomiting, swelling of the abdomen, constipation, hiccup, and great mental depression. All that can be done in the absence of a doctor is to apply hot fomentations, give a dose of castor-oil, and support the patient with nourishing food, given in small quantities at a time.

6. *Intestinal Worms.*—Various worms infest the intestinal canal of man. We will describe the more common species: (*a*) *Trichocephalus dispar*, or long thread-worm, about 2 inches in length, like a bit of yellowish-white thread. (*b*) *Ascaris lumbricoides*, a large round white worm, like an earth-worm, except in colour, found chiefly in children. (*c*) *Oxyuris vermicularis*, the common little white worm, about ½ inch in length, found in great numbers in the lower bowel of children, causing itching and irritation about the anus, picking of the nose, foul breath, and grinding of the teeth during sleep. All these worms may be removed by small doses of jalap or scammony powder (No. 5), or by the administration of from 1 to 5 grains of santonine, according to the age of the child, and followed by a purge of castor-oil. This dose may be repeated. (*d*) *Tæniæ*, the tape-worms, of which there are various species. The symptoms produced by the presence of these large parasites are indefinite, and the only reliable evidence of their existence is the presence in the stools of fragments of the worm, like bits of segmented tape. The remedy of most service is an oil obtained from the male fern. A tea-spoonful of this oil, beat up in mucilage, taken at bedtime, and followed in the morning by a dose of castor-oil, rarely fails in bringing away the intruder.

7. *Diseases of the lower bowel* or *rectum* give rise to much suffering, and always cause depression of spirits and anxiety. Children suffer occasionally from a *protrusion* of the lower part of the bowel, even to the extent of 5 or 6 inches. This usually happens in badly nourished children, and therefore it is of the first importance to improve the general health by nourishing food and tonics, such as small doses of iron (No. 6). When the bowel protrudes, it should be carefully replaced by pushing it upwards with a wet towel or handkerchief; the anus is then to be sponged with cold water, and pressure made on it by a pad of lint or cotton, fixed by a bandage. If these means prove insufficient, consult a surgeon. Adults suffer from various diseases of the anus. An *abscess* may form in the loose tissue round the rectum, which may open internally into the bowel, and externally by the side of the anus. This is then called a *fistula*, and as the irritation caused by it weakens the general health, surgical advice is necessary. A common malady among all classes, but more especially among sedentary people, is known as *hæmorrhoids* or *piles*. Hæmorrhoids are either swollen and congested veins, or they may be simply excrescences of the skin. Occasionally they bleed freely at each stool. They cannot be cured by home treatment, but the symptoms may be palliated. When very painful, bathing with warm water gives great relief. If they are not inflamed, but bleed, bathing with cold water is useful. As they are usually connected with a constipated condition of the bowels, small doses of purgatives, such as magnesia or sulphur mixed with treacle, should be used. No substances which act on the lower bowel (such as aloes) can be given, because they cause much irritation. Plain nourishing food and walking exercise are important. Stimulants are forbidden.

II. DISEASES OF THE ORGANS OF THE CIRCULATION.

The chief organs of the circulation (see PHYSIOLOGY) are the Heart, the Arteries, and the Veins.

1. *The Heart.*—This organ is surrounded by a covering termed the pericardium, composed externally of fibrous tissue, and lined by a delicate membrane which is reflected from the pericardium over the surface of the heart. The two surfaces, in health, glide smoothly on each other. It is often the seat of inflammation (*pericarditis*). The effect of inflammation is to render the membrane (which, in health, is smooth and glistening) dry and rough; and usually there is an effusion between the layers of the membrane of a watery fluid from the blood, called serum. This accumulation of fluid interferes with the action of the heart, and causes great distress. Afterwards, the fluid may be absorbed, and the roughened surfaces of the membrane may again touch, and ultimately firmly adhere together. The heart is then bound to the pericardium, and its free action is interfered with, a result which may lead to other diseases of the organ. Pericarditis may occur suddenly during the course of acute rheumatism, or of disease of the kidneys, attended by dropsy. There is usually pain in the region of the heart, an intense feeling of uneasiness, and high fever. In these circumstances, apply hot fomentations over the heart, and send at once for medical advice.

What is commonly known as heart disease is disease of those valves which guard the various apertures in the interior of the heart, and

direct the current of blood in its proper course. The valves are composed of two or three segments, which, in health, have smooth surfaces and edges, and serve accurately to close the orifices round which they are placed. But inflammation of the lining of the heart causes thickening and contraction of one or more of the segments, and there is often a deposition of lymph on the edge of the segment. The consequence is that the valvular apparatus is seriously injured. The aperture between the cavities may become much smaller than natural, and the valves may be so destroyed as to allow the blood to flow back from one cavity into another, when the heart contracts. This leads to further organic disease. The wall of the heart may become preternaturally thickened, or the cavity may be unusually dilated; the blood may be so arrested in its course through the left side of the heart as to lead to congestion of the lungs, fulness of the right cavities of the heart, and congestion of all the veins returning the blood from the body. This state is followed by the effusion of serum into the cavities of the body, or into the loose cellular tissue under the skin, constituting dropsy. It is evident that disease of the valves can rarely be cured. The patient should be counselled to avoid either mental or bodily excitement. By doing so, in many cases, life may be prolonged for many years. The symptoms associated with an advanced state of the disease can be treated only by a medical man. The term *Angina pectoris* is given to a disease characterised by great and agonising pain in the heart, coming on in paroxysms, accompanied by a feeling of suffocation, and a dreadful sense of immediate death. It is usually a symptom of obscure heart disease. The treatment must be immediate. Give a glass of hot brandy-and-water, and apply a warm poultice over the heart. A doctor should be sent for at once.

Palpitation of the heart is a distressing feeling of the organ beating irregularly. It is sometimes a symptom of heart disease; but in many cases it is caused by indigestion, flatulence, the excessive use of tobacco, or over-study or anxiety. Many people imagine they suffer from heart disease because the symptoms produced by the causes just mentioned may be very similar to those of organic disease of the heart; but a physician, after listening with his stethoscope, is usually able to assure them there is no disease to imperil life. When the causes are removed by suitable remedies, or change of habits, the symptoms quickly disappear. In these cases, a dose of 8 grains of citrate of iron and quinine in half an ounce of water, thrice daily after food, is beneficial.

2. *The arteries* are not liable to acute inflammation. In old people, the lining membrane and walls of these vessels undergo a slow form of fatty degeneration, by which they become weak, and are readily ruptured. This fatty change is often accompanied by the appearance of a faint bluish-white ring round the margin of the cornea of the eye, called the *Arcus senilis*. Many diseases of aged persons, such as paralysis, caused by the effusion of blood into the brain, are due to rupture of the coats of vessels which have undergone this subtle degeneration.

3. Inflammation of *the veins* is termed *phlebitis*. The symptoms are pain, swelling, and redness in the course of the vessel. The swelling may suppurate, and discharge externally; or pus may be formed within the vein, and be carried by the stream of the circulation to distant parts of the body, such as the lungs or liver, giving rise to serious affections of these organs. The treatment is complete rest, hot fomentations, and, if the person be weak, nourishing food and a glass or two of port wine daily.

III. DISEASES OF THE ORGANS OF RESPIRATION.

1. *The Air-passages.—Catarrh.*—This affection is known as a cold, and consists of inflammation of the mucous membrane of the air-passages. It may be limited to the lining of the nose and of the cavities in the frontal bone over the eyebrows, when it is termed a *coryza;* or it may extend to the lining of the windpipe and bronchial tubes in the lungs, when it receives the name of *bronchitis*. The symptoms of a cold are well known. The disease runs a natural course, and is not much affected by any medicines. Bathing the feet in hot water, the application of a poultice to the chest, if there be much irritation or tightness in that region, and perhaps ten grains of Dover's powder at bedtime, is all that is necessary.

2. *The Larynx.*—Loss of Voice, or *Aphonia*—The voice is produced by the vibration of the vocal cords of the larynx, caused by the current of air passing upwards from the lungs in expiration. The cords consist of two thin membranous bands passing from before backwards, attached by one border to the side of the larynx, and having the other border free. The two free borders have a narrow slit or chink between them, termed the glottis. To produce voice, these cords must be of uniform thickness, and both must be at liberty to vibrate with the same rapidity. Hence it is that a wart or small tumour even on one cord, or paralysis of one cord, or even thickening of one cord, always causes loss of voice. In hoarseness during a cold, the cords are inflamed and thickened. After protracted speaking or singing, or after singing high notes, the cords may become dry, when partial hoarseness is the result. Hoarseness from these causes is temporary; but if permanent, it is probably due to some organic affection, such as a tumour, which can be dealt with only by a surgeon specially skilled in the treatment of diseases of the throat. In recent times, a great advance has been made in the detection and treatment of diseases of the cords by the invention of the laryngoscope. This instrument consists of a small mirror fixed at the end of a slender handle, at such an angle that when placed at the back of the throat, an image of the opening of the larynx, with a view of the vocal cords, is readily seen. Occasionally we meet with cases of loss of voice in which no disease whatever can be detected. It is then dependent on a nervous disorder, and all that can be done is to improve the general health.

Croup is a disease so common among children, and often so fatal, if not attended to at the outset with prompt skill, as to merit our careful attention. It is an inflammatory affection of the lining membrane of the larynx and trachea, accompanied by the development of membranous matter on the inflamed surface. It usually commences with the symptoms of a cold, such as cough, fever, restlessness, and running at the nose.

The cough soon acquires a harsh ringing sound, and respiration becomes more and more difficult. Inspiration is prolonged so as to produce a peculiar crowing sound, which cannot be described. The inside of the throat is red and swollen, the tonsils are enlarged, and are usually covered by a quantity of tough mucus. The treatment is to place the child immediately in a warm bath, give a tea-spoonful of ipecacuanha wine to a child two years of age (and less or more according to age), apply a warm poultice to the throat, and send for the doctor. If no doctor can be found, give doses of ipecacuanha wine till the child becomes sick and vomits freely. The act of vomiting causes coughing, which dislodges the false membranes in the larynx, and clears the respiratory passage. Keep the child in a warm room, wrapt up in hot blankets or flannel. This is all that can be done by a non-professional person.

There is a kind of false croup, known as *Laryngismus stridulus*, which attacks children during teething, not to be confounded with true croup. It is a spasmodic closure of the glottis. The attack is sudden; the child screams and kicks, and seems in danger of perishing from suffocation. In a very few moments, there is a loud whistling or crowing sound, produced by the air again rushing into the lungs through the glottis, and the child is soon well. This affection is an example of what physiologists term a reflex action. Irritation of sensory nerves is caused by teething, or by undigested matters in the bowel; this irritation goes to a nerve-centre, such as the brain or spinal cord, and from the centre, an influence passes along another nerve, called a motor nerve, to the muscles of the larynx, causing them to contract so as to close the glottis. The treatment is to excite inspiration by dashing cold water on the face and head, slapping the chest, &c. Afterwards the bowels should be unloaded by castor-oil.

Diphtheria is a disease caused by a specific poison entering the blood, which affects the nervous system, and manifests itself by a peculiar inflammation of the throat or respiratory passages, or both. It frequently occurs during epidemics of scarlet fever, to which disease some suppose it to be allied. There is no doubt that many cases of sore throat are stated to be diphtheritic which are not so; indeed, it requires considerable experience to enable one always to identify the disease. The early symptoms are those of a cold with sore throat. On examining the interior of the throat, a few specks or patches of a gray ash colour may be seen on one or other tonsil, or on the back of the throat, or on the uvula. These patches spread so as to form a membrane like a slough or bit of washed leather, which can be separated from the mucous membrane, leaving exposed a raw-looking and bleeding surface. Coincidently with these appearances, there may be difficulty in swallowing, or in respiration, and the strength of the patient diminishes at an alarming rate. Death may occur from exhaustion, or from suffocation owing to the spread of the exudations or patches to the air-passages. In cases of recovery, the patient remains sometimes weak for several weeks, with partial loss of voice, squinting of the eyes, and even of partial paralysis of the lower limbs, shewing that the poison has attacked the nerve-centres. A disease so serious must be treated by a medical man. In his absence, gargle the throat with a strong solution of Condy's Fluid (permanganate of potash), and support the patient's strength by strong beef-tea, and a glass of good port wine every few hours. The room should be warm, and the air moist, and relief may be obtained from distressing symptoms by inhaling the vapour of warm water.

3. *The Bronchial Tubes.*—These tubes serve the function of conveying air to and from the lungs. They are lined by a delicate membrane, which, when inflamed, causes the disease known as *bronchitis*. This affection may be acute or chronic. In cold and damp climates this disease is common, acute at all ages, and chronic chiefly among old people. The symptoms of *acute* bronchitis are fever, pain in the chest, cough, and the expectoration of viscid or pus-like mucus. There is also loss of appetite, headache, and other constitutional effects. These symptoms are present in other diseases of the lungs, and an examination of the chest with the stethoscope is necessary to discriminate the one disease from the other. It is beyond the province of this article to describe the sounds heard by this instrument, which serves as a conductor of sound between the chest of the patient and the ear of the physician. Without it, our knowledge of chest affections would be meagre indeed, and one can scarcely over-estimate the importance to humanity of the invention of this little instrument. The application of mustard plasters to the chest, and a cough mixture (No. 7), will usually relieve the patient, who should remain in bed in a warm room. If there be much debility, beef-tea and arrowroot and milk should be given freely. *Chronic* bronchitis is the winter-cough of old people. If it has occurred frequently, it may lead to dilatation of the bronchial tubes, causing condensation of lung-substance, and consequent breathlessness. Occasionally it assumes an acute character, passing rapidly to the smallest bronchial tubes, when it is usually fatal. Substances which stimulate the secretion from the tubes are prescribed in this disease, such as squills, ipecacuanha, &c. a useful combination of which will be found in a prescription (No. 8).

The smaller bronchial tubes are surrounded by a layer of muscular tissue, which, by its property of contractility, is capable of changing their calibre. A spasmodic contraction of this layer constitutes the disease called *asthma*. This affection is often hereditary. It may be caused by inhaling irritant vapours, or, in some individuals, by the presence of too much food, or of irritating food in the stomach. The fit comes on suddenly. There is a sense of suffocation. The patient sits or stands, and seizes hold of some article of furniture, so as to fix his arms, and thus allow the muscles of inspiration to act to the greatest advantage. He gasps for breath, and sometimes throws open the window, even during the night, to admit air. The countenance is slightly bluish in colour, the expression is anxious, the skin is cold and clammy, the pulse is feeble. At length the sufferer coughs up a few little masses of mucus, and obtains relief. All of these symptoms are referable to deficient oxygenation of the blood, from the obstruction to the free ingress and egress of air to the air-cells of the lungs. An asthmatic person should seek to improve the general health as much as

possible by nutritious diet, bathing, exercise in the open air, and attention to the choice of digestible articles of food. He should eat frequently, and little at a time; above all, avoid late suppers. During the attack, admit air freely into the room. The remedies for asthma are numerous, and should be taken only with medical advice.

4. *The Lining Membrane of the Chest.*—The chest is lined by a delicate and smooth membrane called the pleura, which is reflected over the surface of each lung. There are thus two pleural spaces, one for each lung; but in health there is, in reality, no space, the pleural surface of the lung always coinciding with, and gliding upon, the pleural surface of the wall of the chest. When this membrane is inflamed, we have a disease called *pleurisy*. As in pericarditis, inflammation first renders the membrane dry and hard; afterwards, it becomes covered with a layer of matter called lymph, and serum may be exuded so as to separate the two pleural surfaces. The quantity of serum thus exuded may be very small, or there may be many pints of fluid. This latter condition is called *hydrothorax*, or water in the chest. The fluid may become absorbed, in which case the pleural surfaces frequently adhere together. At other times the serum may become purulent, when we have *empyema*, or pus within the chest. This accumulation of pus may become absorbed; or it may pass into the lung, and be coughed up; or it may escape by an opening through the walls of the chest. Pleurisy is not usually a fatal disease, but it requires skilful medical treatment. The symptoms are well marked. The most distinctive are an acute pain in the side, called a stitch, limited to one spot, which is aggravated by deep inspiration or coughing. There is feverishness. On placing the ear over the chest, a peculiar rubbing or crackling sound is heard, produced by the friction of the roughened pleural surfaces. When fluid accumulates, this sound disappears, and the chest may bulge out on one side. The patient instinctively prefers to lie on the affected side, so as to allow the healthy lung to act freely. In the early stage of pleurisy, apply hot poultices or fomentations to the chest, and send for a doctor.

5. *The Lungs.*—Acute inflammation of the lungs is called *pneumonia*. It is divided by physicians into three stages. In the first stage the lung becomes congested with blood. The patient is feverish, has difficulty in breathing, and suffers from pain in the side, more diffused over a surface than that of pleurisy, which is limited to a spot. There is cough, with expectoration of viscid mucus, tinged with blood so as to have a rust-colour. In the second stage, the lung loses its healthy spongy character altogether, becoming hard and solid. The third stage is characterised by diffuse suppuration of the lung tissue. The sputa then becomes quite purulent. Pneumonia of a portion of one lung is not usually a fatal disease if it occur in a young and vigorous adult; but when uncomplicated, tends towards recovery on or about the fourteenth day from the beginning of the attack. If the disease occur in an aged person, or in one whose constitution has been in any way debilitated, the result may be death. The disease may affect one lung or both: inflammation of even a portion of both lungs is, of course, a more serious affection than inflammation of one. The right lung is oftener affected than the left, and the bases of the organs are oftener inflamed than their apices. The disease is usually complicated with bronchitis, and occasionally, when the disease affects the superficial parts, the pleura becomes involved, and we have then a case of pleuro-pneumonia. The treatment of this disease has undergone a great change in recent times. Twenty or thirty years ago, patients were freely bled, and were subjected to the action of strong salines, tartar emetic, mercury, and other debilitating drugs. Now, however, with the view of conducting the disease to a natural termination, and to ward off complications, the treatment may be described as consisting chiefly in the administration of a nutritious and easily assimilated diet, such as good beef-tea, along with a moderate allowance of stimulants. Small doses of sweet spirits of nitre, along with acetate of ammonia, are given to allay feverishness (No. 9). In this respect, there has been a great improvement in practice, and a considerable decrease in the mortality of the disease. In the early stages of the disease, apply hot fomentations, or, still better, poultices made of oatmeal, linseed meal, or bran, so large as even to enwrap the chest.

Phthisis, or Consumption.—The disease we have now to describe is, unfortunately, very common in the British Islands, nearly one-fourth of the total number of deaths occurring in one year being due to it. Phthisis may be hereditary, or it may be acquired by habitual exposure to impure air, excessive study, the use of a non-nutritious diet, intemperate or unchaste habits, or by any cause which weakens the vital energy of the body. It may occur in all ranks, and at all ages; but it is much more frequent before than after forty years of age. In most cases, it runs its fatal course in from twelve to twenty-four months; but occasionally it proves fatal in twelve, eight, or even six weeks. The morbid change in the lung which is at the root of the disease, so far as this organ is concerned, is the formation in the tissues around the ultimate air-cells, and even in the cells themselves, of tubercle. Some pathologists maintain that this substance is due to the presence of microscopic organisms called *bacilli;* others that it originates in an exudation from the blood, or is a morbid development of part of the lung tissues. It appears at first in the form of small round, grayish masses like millet-seeds, and is then called miliary tubercle. These are usually deposited in the apex of the lung, which is beneath the collar-bone. The disease rarely commences in the lower lobes of the lung. These masses fuse together, and undergo a sort of fatty degeneration or change, so as to form a matter like friable cheese, of a yellow colour. The presence of this morbid product in the lung excites inflammation and suppuration, the tubercular matter softens and breaks down, the tissues around it become more or less ulcerated, and the débris is coughed up, leaving cavities behind of various sizes, from that of a split pea to that of an orange. These cavities may contract and completely heal up, leaving a cicatrix; but, unfortunately, the disease advances by fresh tubercular matter being deposited in an adjacent part of the lung. The symptoms are: failure of the general health, loss of appetite, a strong dislike to fat in any form in the food, a short dry cough, and a quick pulse. In some cases, the

expectoration is occasionally streaked with blood, or there may be severe bleeding from the lungs. As the disease progresses, the cough becomes more distressing, is often deep and hollow, and there is an expectoration of purulent matter, often in the form of flattened circular masses. The patient becomes weaker, from the occurrence of copious perspirations during the night, and the violence of the cough. The body gradually wastes. In the centre of each cheek there is often a diffuse spot of a delicate rose-tint, the eyes become pearly white and brilliant, and the patient has a refined and spiritual appearance peculiar to the disease. The intellect is unimpaired, and hope is usually strong. Death is caused by exhaustion, or by an acute attack of pleurisy or pneumonia, or by a severe hæmorrhage or bleeding. The symptoms above described are so characteristic, that it does not require the art of the physician to detect the disease; but by means of the stethoscope, he can watch its gradual development, and can usually give information regarding the exact condition of the lung. With regard to treatment, it is of the greatest importance to improve the general health. Anything calculated to cause mental or bodily irritation should be got rid of. The patient should be much in the open air during fine weather, and should take a nutritious diet. If bleeding take place, the blood is of a bright red colour, and is frothy. The treatment then is: rest in the recumbent posture, cold drinks, sucking ice, and the administration of ten grains of gallic acid, or one lead and opium pill every three hours till the bleeding ceases. Consumptive persons have usually weak powers of digestion, and suffer from dyspepsia; and the diet suitable in one case may not be so in another. Relatives should therefore study the likes and dislikes of the patient, and endeavour, with the art of good cookery, to introduce into the body, in one form or other, milk (with lime-water, if there be acidity of the stomach), eggs, butter, cream, beef-tea, &c. A glass of good wine daily, or bitter beer, is often useful.

The next point to be attended to is climate. There can be no doubt that in many cases of consumption, life may be prolonged, and even saved, by a judicious selection of a warmer and more equable climate than that experienced in most parts of the British Islands. The difficulty is, that few can afford the expense of living at a distance from home. But change even to a distance of a few miles into the country may do good. During the summer season, residence on the west coast, by the side of one of the sea-lochs, where the patient can be out in the open air for several hours daily, is always beneficial during the earlier stages of the disease. If the expense can be borne, the patient may reside during the winter at Torquay, Hastings, Bournemouth, or Penzance; and on the continent, at Mentone, Cannes, or Nice. No journey should be undertaken to any of these health resorts without medical advice, because the climate of the one is not the same in many particulars as that of the other, and one place may be more suitable for certain cases than for others. During an early stage of the disease, a sea-voyage is often very beneficial, but it should not be taken without consulting a medical man. It is often a very difficult task for the family physician to give advice as to going abroad, and yet the matter must be left to the decision of one who knows all the circumstances of the case. No doubt many have sailed for foreign lands who should have remained at home; but, on the other hand, there are persons now alive in such colonies as New Zealand and Natal who would, in all human probability, have been in their graves had they remained in their native country. With regard to medicines, it may be stated generally that in phthisis they are not of much avail, except in the alleviation of symptoms. Nauseating cough-mixtures should be avoided, as they impair appetite. The great remedy is cod-liver oil, which supplies fatty matter to the system. This oil should be regarded as a form of food more than as a medicine. Most persons can take it after a little experience, and the results are almost always good. Small doses, such as a tea-spoonful, should be taken at first; these may be increased to the extent of a table-spoonful twice daily after food. If cod-liver cannot be borne by the stomach, cream, or milk and egg, should be substituted.

IV. DISEASES OF THE ORGANS OF EXCRETION.

The organs of excretion separate from the blood matters hurtful to the economy. They are the Bowels, the Lungs, the Liver, the Kidneys, and the Skin (see HUMAN PHYSIOLOGY). The diseases of the bowels and lungs have been already described; those of the skin are so numerous, and require such special experience and knowledge for their identification, as to place it beyond the limits of this article, even to enumerate them, far less to state their leading characteristics. We have, therefore, now to deal with the affections of the liver and kidneys.

1. *The Liver.*—This large gland is liable to congestion and inflammation, both acute and chronic; but as these diseases are not common in this country, we shall not describe them. There is a form of inflammation of the organ which is not unfrequent, called *cirrhosis*, or spirit-drinker's liver, which is frequently met with. It occurs usually in persons of middle life who have been in the daily habit, for years, of introducing a considerable quantity of alcohol into the system. Alcohol is taken up by the blood-vessels of the stomach, and conveyed by them to the liver. Here it excites chronic inflammation of the connective tissue between the small lobules of the liver, and causes an hypertrophy, or increase in growth of this tissue. At this period of the disease, the organ is enlarged, and its edge may be felt extending far into the left side of the abdominal cavity. After a time, the tissue contracts, and presses on the blood-vessels supplying the lobules, so as to prevent these obtaining a due amount of blood. This leads to an atrophy or wasting of the proper secreting structures of the liver—the hepatic cells; and the gland, in consequence, does not efficiently perform its functions. At this stage, it is smaller than natural, and its surface is uneven, presenting little lumps or knobs, which may be felt through the abdominal wall. The patient's general health suffers, the skin becomes yellow or jaundiced, and from the obstruction to the flow of the blood (collected from the stomach and bowels) through the liver, dropsy, or the effusion of serum into the abdominal cavity, is the result. This disease is fatal, and is a sad example

of one of the effects produced by habitual over-indulgence in intoxicating liquors.

The affection with which disorders of the liver are commonly associated is *jaundice*, in which the skin and white of the eyes assume a yellow colour. Jaundice is not a disease in itself, but a symptom. It may be produced in one of two ways: either by the liver ceasing to secrete bile, and consequently leading to an accumulation of the colouring-matter of that fluid in the blood; or by an obstruction to the flow of bile from the gall-bladder into the bowel, and the re-absorption into the blood of the colouring-matter. Jaundice occurs much more frequently from the latter than from the former cause. The bile ducts may become plugged up by mucus, or by a concretion from the bile called a gall-stone, or by tumours. In whatever way jaundice may be produced, the general symptoms are much the same—namely, the yellow skin; the yellow eye; the urine becomes dark in colour, and on the surface has a greenish lustre; the fæces are like white clay; the tongue is covered with a thick yellowish-white fur; the appetite is gone; and the pulse is usually very slow. The treatment, of course, depends on the cause. If there are reasons for believing the bile is not secreted, the liver is stimulated by small doses of such drugs as sulphate of soda (10 grains to a dose) with decoction of taraxacum; if, on the other hand, the jaundice arises from obstruction, mild purgatives, such as colocynth or rhubarb pill, should be given. Rest in bed, and a diet free from fatty matter, are necessary.

The passage of a *gall-stone* from the gall-bladder into the bile-duct, is attended with excruciating pain, limited to one spot in the region of the liver, and usually on the right side of the vertical median line of the body. The patient is in agony; and there may be much nausea and vomiting from irritation. To relieve the great pain, cover the whole abdomen with hot fomentations, frequently renewed, and give to an adult 25 to 30 drops of laudanum in half a glass of water. This dose may be repeated at the end of two hours, if the pain continue.

2. *The Kidneys and Urinary Organs.*—Affections of the kidneys are obscure in their origin, course, and termination, and require for their detection and treatment more special knowledge than can be communicated here. We must therefore give an idea of their general character, and of those symptoms which call for medical assistance. The kidneys are subject to *inflammation*, both acute and chronic. The inflammation may involve all the tissues of the organ, or only the lining membrane of the tubules of which it is composed. General inflammation of the kidney is rare; but acute inflammation of the lining membrane, leading to a shedding of the secreting epithelium cells which cover the membrane, is far from uncommon. This latter affection is called *desquamative nephritis*, or inflammation of the kidney, attended by the desquamation or shedding of the cells just alluded to. It frequently follows an attack of scarlet fever. After this disease, the epidermis of the skin peels off in large scales or flakes. If, in these circumstances, the patient is exposed to a chill, or indulges in a diet containing too much nitrogenous material, more work is laid on the weakened kidney than it can perform, and the disease under consideration is the result. The obvious feature of the disorder is dropsy, commencing in the face as a puffy, white swelling beneath the eyes. The urine is scanty, dark-coloured, from the admixture of blood; and if a small quantity be boiled over a gas flame in an iron spoon, it becomes muddy, from the coagulation by heat of albumen, a substance found in blood, but not in healthy urine, but which has passed out of the vessels into the tubules of the kidney in this disease. If the disease be not arrested, the functions of the kidney as a purifier of the blood from nitrogenous matters are interfered with, and there is consequently an accumulation in the blood of a substance called urea, which may act directly or indirectly on the brain and spinal cord, and destroy life. The treatment of this disease is residence in a warm room, the use of a warm bath, a milk diet, and, for a child of 10 or 12 years of age, 8 or 10 grains of compound jalap powder daily, to drain off fluid by the bowels.

There are a number of grave diseases of the kidney grouped under the general name of *Bright's disease* (named after a distinguished physician who first described them). They consist in various forms of degeneration of the secreting structures of the kidney, leading to an impoverishment of the blood, by the daily escape of albumen in the urine, and otherwise interfering with the functions of the organ. These cases can be recognised and treated only by a medical man.

The disease known as *diabetes*, though usually grouped under diseases of the kidney, is not really a disease of that organ. It is characterised by the passage of a large quantity of urine, which contains a sugar identical with grape-sugar, in most kinds of fruit. The nature of the disease is not yet understood. A substance allied to sugar is formed in the liver, and there are physiological reasons for believing that this material is converted into sugar in the blood. The ultimate destination of this sugar is not known, but it is supposed to be converted into carbonic acid and water. The nervous system influences this sugar-producing function of the liver, because it has been found that artificial injury to a particular part of the brain in animals is followed by the appearance of sugar in the urine; in fact, it produces temporary diabetes. Whether the origin of diabetes is in the brain, or in the liver, or in both organs, is not at present known. The general symptoms are: muscular debility, gradual wasting of the body, a dry skin, great thirst, and the passage of a large quantity of urine. Occasionally, more especially in aged persons, the urine is not much increased in quantity. The disease is often associated with tubercular lung disease, and is almost always fatal. In young persons from 18 to 30 years of age, it is invariably fatal within a period of two to five years; but when it occurs in aged people, it does not advance so rapidly, and the natural period of life may not be shortened. It is a disease for which, in the present state of science, little can be done.

The state of the *urine* frequently indicates disorders which otherwise might pass unnoticed. At the same time, persons often distress themselves unnecessarily when they observe changes in the excretion, which may be caused by very trivial deviations from a healthy state. In health, about 2 pints of urine are passed daily. It has a golden

amber colour usually, but it may be pale or dark. A dark-coloured urine is a concentrated urine, containing a smaller proportion of water to solid constituents than one which is light-coloured. Sometimes the urine, when held up in a glass vessel between the eye and the light, has a smoky appearance from the admixture of blood. When the urine is dark green, and has a greenish lustre on the surface when agitated, it contains bile. Diabetic urine is usually pale, and has a peculiar sweetish odour, like that of newly mown hay. Sometimes, when the urine cools, a sediment or deposit falls to the bottom of the vessel. This deposit consists of urates of potash or soda—salts always found in healthy urine, of which there may be an excess excreted. As they are more soluble in hot than in cold water, the urine is clear when passed; but on cooling to a temperature of 50° F. or so, the urates which exist in excess of that soluble in the amount of fluid are deposited as a sediment. Deposits of urates may be nearly white, but they are usually pink coloured. On heating the urine, the deposit is at once dissolved. Urates may be found in excess after or during slight derangements of digestion, or after feverish attacks, or during recovery from severe inflammations. When urine is allowed to stand exposed to air, it ferments, and acquires a strong and disagreeable ammoniacal odour, while there is a deposit usually of a whitish colour. This deposit consists of phosphate of lime, and of a salt called the triple phosphate of ammonia and magnesia. In some diseases, such as inflammation of the bladder, or during paralysis, the urine is passed in this ammoniacal condition. Such a state of matters requires medical advice. Excessive acidity of the urine is characterised by producing a hot, burning sensation when passed. Such urine changes the colour of a bit of blue litmus paper to an intense red. Acidity usually arises from some error in diet, such as eating too much animal food, and is readily removed by the use of fresh vegetables, and by drinking barley-water or tea.

Inflammation of the bladder is a severe disease. There is pain over the lower part of the body; a constant desire to pass urine, which is voided in small quantities; and there are severe constitutional symptoms, such as fever, sickness, and depression of spirits. The employment of a hip-bath, or the application of a large moist linseed poultice over the lower part of the abdomen, will give relief till a medical man arrives. The lining membrane of the bladder is liable also to chronic inflammation, frequently caused by the presence of a calculus or stone in the viscus, for which surgical advice is necessary.

V. DISEASES OF THE NERVOUS SYSTEM.

The nervous system may be divided into the Brain, the Spinal Cord, and the Nerves.

1. *The Brain.*—This important organ is covered by several membranes called the meninges, which serve for protection and for the distribution of blood. These membranes may become acutely inflamed, constituting a disease known as *meningitis.* This serious affection is ushered in by severe pain in the head, irritability of temper, intolerance of light, delirium, and high fever. There is constant vomiting or retching, even after the stomach has become quite empty. The tongue is clean, and there is usually obstinate constipation. Matters go from bad to worse, till the patient sinks into a state of profound insensibility, caused by the pressure of fluid on the surface of the brain, and death terminates the disease. This affection may be caused by incautious exposure of the head to the sun's rays, by blows on the head, or by the extension of inflammation from disease of the internal ear. The symptoms of inflammation of the substance of the brain itself are very similar to those just described, and the result is death.

There is a form of meningitis in children of a delicate type of constitution, which unfortunately is common in this country. It is called *tubercular meningitis*, because it is caused by the deposition of tubercle in a portion of the membranes covering the base of the brain. Sometimes it is termed acute hydrocephalus. It occurs in children under five years of age; and it is most important for parents to be acquainted with the premonitory symptoms, because it is only during the very early stages of the disease that there is any hope of saving life. Usually, the child is badly nourished. There is irritation of the temper, inability to bear a full flood of light, slight feverishness, a dry skin, vomiting, and loss of appetite. The child seems to be afraid of falling from its mother's arms, probably from a feeling of giddiness, and prefers to lay its head on her shoulder. When in bed and asleep, it rolls its head from side to side on the pillow, and grinds its teeth. The tongue is furred, and the motions from the bowels are offensive and dark. There is frequently constipation. In these circumstances, parents should, without delay, summon the doctor. It is too serious a complaint to allow an hour to pass without medical help. The children of scrofulous parents should have cod-liver oil given as a food (a tea-spoonful twice daily) at any time when nutrition is imperfect.

Water in or on the brain, or hydrocephalus, is a disorder caused by the accumulation of serum in one or other of the cavities in the brain termed the ventricles; or the fluid may be on the surface of the organ. The quantity of fluid varies from a few ounces to several pints. When large, the bones of the skull are so displaced by distention as to cause the cranium to become globular, and the protruding forehead overhangs the small and often wasted face. The body is also much emaciated. The treatment of these cases is not hopeful; but still, surgeons have succeeded in saving life.

Apoplexy is the name given to that condition in which a man suddenly falls down insensible, as if by a blow. It may be caused in various ways, such as the sudden rupture of a vessel in the brain, and consequent pressure on the brain-substance by effused blood; the sudden interruption of continuity of nerve-substance in the brain, by softening; or the plugging up of a vessel in the brain by a small clot carried in the circulation from perhaps a distant part of the body. The symptoms are: loss of consciousness; a full, strong, sometimes intermittent pulse; slow snoring breathing; a dull, glassy, staring eye; and a cold clammy skin. Patients often survive one, or even two attacks of this nature, but always with impairment of intellect, and partial or complete loss of motion, and of sensibility of the upper and lower limbs on one side of the body. What is to be done when an attack has

occurred? Lift the person carefully to a cool airy room, elevate the head, take off the cravat or neck-tie, loosen the shirt-collar, and send for a medical man. Persons who, from hereditary constitution, or from fulness of body, are liable to apoplectic attacks, should lead quiet and regular lives, avoid stimulants, sleep with the head well elevated, and the neck free from constrictions, and bathe the head frequently. The bowels should never be constipated. If subject to giddiness, or sudden confusion of ideas, a seton or issue in the back of the neck may be put in by a surgeon, as a counter-irritant.

Concussion of the brain is caused by a severe blow on the head. There is, according to the force of the blow, a condition more or less approaching unconsciousness. There is also confusion of ideas. The pupils are insensible to light. The skin is cold, the breathing can scarcely be detected, and the pulse is feeble and irregular. This condition should be distinguished from that following compression of the brain, where we have deep snoring respiration and a full pulse. In all doubtful cases, as, for example, when a man is found insensible in the street, the odour of the breath should be observed, because drunkenness may be the origin of the insensibility, and it may be neither a case of apoplexy nor of concussion. At the same time, a drunken man may become apoplectic, an event which has occurred in police cells. The treatment of concussion is quietude and rest, with the administration of a little wine or brandy diluted with water.

Habitual intemperance produces a disease called *delirium tremens*, on account of the trembling of the muscles which is associated with the delirium. There is complete loss of appetite and sleep; the patient looks haggard and restless; may answer questions rationally, but when allowed to follow the current of his own thoughts, talks nonsense; and he usually suffers from hallucinations of the senses, fancying he sees spectres, hears mysterious sounds, or feels vermin crawling over his body. The treatment is dietetic, medical, and moral. In the first place, the sufferer should be compelled to take a considerable quantity of strong concentrated beef-tea, to nourish his exhausted body; secondly, a dose of thirty grains of the hydrate of chloral in two ounces of water should be given, to cause sleep, and the dose may be repeated at the end of two hours if necessary; and thirdly, he should be cut off from all intoxicating liquors, and be quietly restrained from mischief by a strong male attendant. Repeated attacks of delirium tremens weaken the mental powers, and may induce insanity—another sad instance of the result of abusing the use of alcoholic liquors.

Headache is a very common complaint, but it may arise from various causes. Frequently it may be termed a bilious headache, because it is associated with derangement of the digestive organs, produced by an error in diet. An ordinary laxative quickly removes this variety. Full-blooded people, of a stout habit of body, may suffer from headache and giddiness, which is relieved by a purgative and low diet. Nervous persons, of weakly constitution, are liable to severe headaches, which may be diffuse, or limited to one side of the head. There is no disturbance of the digestive organs. Such headaches may be caused by the irritation of decayed teeth in the gum. These should be removed. A dose of two grains of quinine three times daily will be found beneficial. Lastly, when headache is severe, constant, limited to one part of the head, and not apparently connected with disorder of the digestive system, disease of the brain may be the cause.

2. *The Spinal Cord.*—The spinal cord is the channel of communication between the brain and the body, and it is also the centre for numerous reflex actions (see PHYSIOLOGY). Consequently, any disease of the cord which affects its structure is attended by paralysis, or loss of power of movement. The cord is liable to inflammation, both acute and chronic; to softenings; to the pressure of tumours; to pressure from diseased bone in curvature of the spine; and to concussion or shock from severe jolts, such as may be got in a railway accident. These diseases are all dangerous, and require medical or surgical skill.

By *paralysis* we mean the total or partial loss of sensibility or motion, or of both, in one or more parts of the body. If the sensory nerves, which convey impressions from the circumference of the body to the brain, are alone affected, we have partial or complete loss of sensibility; if, on the other hand, the disease affects the part of the central nervous system from which the motor nerves (which carry impressions from the brain to the muscles) originate, or the nerves themselves, the condition is loss of motor power, partial or complete. Paralysis may be local, as when a special nerve is paralysed, or it may be more general. When one side of the body is paralysed, the disease is almost invariably in the brain, and is termed *hemiplegia.* When the two lower limbs are paralysed, the spinal cord is the seat of the disease, which is called *paraplegia.* Hemiplegia of one side, say the right, indicates disease in the brain on the opposite side—that is, the left. This is owing to the fact, that the great majority of the nerve-fibres which pass from the right half of the brain, cross over at the upper part of the spinal cord, to supply the left side of the body; while those from the left half pass to the right side. In hemiplegia, as the disease is cerebral, there is usually more or less disorder of the mental faculties; but such is not the case in paraplegia, the disease being in the cord. In both kinds of paralysis, the muscles undergo fatty degeneration and waste from disease, unless daily stimulated to contract by electricity. Details as to the treatment of paralysis cannot be given in the limits at our disposal. There is a form of local paralysis of one-half of the face produced by sitting in a cold draught of air, such as exists at the window of a railway carriage. The cause here is the effect of cold on the nerve supplying the muscles of expression on one side of the face. The features on one side lose the power of expression, and the eye on the affected side remains wide open from paralysis of the muscle which closes the lids. There is usually no loss of sensibility. This affection is purely local; it does not indicate any disease of the brain; and it usually disappears at the end of 12 or 14 days, the nerve slowly regaining the power of exciting the muscles on the affected side to contract properly. Painters, and other operatives who work with lead, suffer from paralysis of the extensor muscles of the fore-arm, so that they cannot, by any effort of will, raise the hand, but

allow it to hang downwards. If the mouth of the person so affected be examined, a blue or purplish line will be found round the gums where they join the teeth. The patient also has occasionally severe colic or cramping pains in the stomach and bowels. The treatment is to give in the first instance a mixture containing sulphate of magnesia (Epsom salts), along with sulphuric acid, by which a large amount of the lead with which the system has become impregnated will be eliminated, and afterwards, for several weeks, the patient should take 5 grains of iodide of potassium three times daily. During the cramp, the application of hot poultices over the bowels will give relief.

3. The *nerves* of the body may be pressed on by tumours, or they may become inflamed, or be irritated in the neighbourhood of an inflamed part, so as to give rise to severe pain. This constitutes *neuralgia*. The most common form is called tic douloureux, in which there is severe pain over the eyebrow, which may shoot over the cheek, side of nose, and lower eyelid; or is referable to the lower jaw and side of the neck. It is usually confined to one-half of the face. The cause is often the presence of decaying stumps of teeth in the gums, disorder of the digestive system, weakness from over-anxiety, over-work, or imperfect nutrition, or a rheumatic state of constitution. The removal of the stumps will frequently cure the disease. Tonics are often required; the one found most beneficial in this case is quinine, in doses of two or three grains thrice daily. If the attacks come on at or about the same hour daily, a dose of four or five grains of quinine, taken half an hour before the attack, will often ward it off. During the pain, the application of hot fomentations, or of camphorated liniment having a proportion of laudanum, may give relief.

VI. FEVERS.

These diseases form a large group of what are called zymotic diseases (from *zumoō*, to ferment), because they are supposed to be caused by the introduction into the blood of a poison which acts on that vital fluid in a manner resembling that of a ferment. The nature of these fermentive poisons has never been demonstrated, but their existence and nature are assumed from the following considerations: 1. These diseases are capable of being communicated from one human being to another through the medium of the atmosphere, either from the breath, from particles of matter shed from the surface of the body, or from emanations from the excrements. They are found to vary in this respect; scarlet fever, for example, being much more contagious than typhoid fever. 2. After exposure to the influence of the disease, there is a period of incubation, during which the poison is supposed to affect the blood slowly, rendering it unfit for the healthy nourishment of the tissues, or communicating to it qualities which may excite, or even poison the tissues. 3. The period of incubation is succeeded by severe symptoms of constitutional disturbance, such as shivering, weakness, heat of skin, and quick pulse. 4. These symptoms increase until there is a period of crisis, at which there is frequently a change in the symptoms. The patient, to use common language, 'gets the turn.' This period is frequently marked by a critical event, such as bleeding from the nose, profuse perspirations, a discharge from the bowels, or a flow of dark-coloured urine, which, after cooling, gives a copious deposit. 5. After crisis, the patient gradually recovers. During the progress of the disease, the patient is at all times liable to be affected by more or less serious complications, such as suppurations, inflammation of the lungs, &c.; and these complications vary in character in each fever, and even at different stages of the same case. 6. Recovery from an attack of any of those diseases usually, but not always, secures immunity from the action of the poison though again exposed to its influence. The fevers common in Great Britain may be thus divided: 1. Continued fevers, including (*a*) simple summer fever, (*b*) typhus, and (*c*) typhoid, enteric, or gastric fever; 2. Fevers having an eruption on the skin—namely, (*a*) chicken-pox, (*b*) small-pox, (*c*) measles, and (*d*) scarlatina. As it is manifestly impossible to give an account of all of these in this paper, we will arrange the more important facts in the form of a table (see next page), so that a comparison may be readily made between the various kinds.

Except in extremely mild cases, the treatment of all fevers should be under the direction of a doctor, because unlooked-for complications may arise which may imperil the life of the patient. The treatment of fevers consists really in the treatment of symptoms. We do not attempt to annihilate the disease; it marches through its course triumphantly, because we do not yet know its real cause, and all we can do is to lessen as far as possible the evil effects it produces. The time may come, and, from a purely scientific point of view, we have every reason to expect it will come, when the active physiological properties of the substances causing those various fevers will be known, and when we shall have learned, by experiment and observation, to antagonise, and even to annihilate those actions. At present, the physician cannot do so. He has to wait and watch, meeting new complications by the resources of his art as they appear from day to day, and supporting the strength of his patient by nourishing food and wine, so as to maintain the vital action of the body as much as possible. When complications do arise, these are treated according to the knowledge, experience, and skill of the physician.

VII. DISEASES OF THE BLOOD.

These are numerous, and can only be briefly referred to here. *Scurvy* is a disease due to a deficiency of the salts of potash in the blood, owing to the privation of fresh vegetables. The treatment is a vegetable diet, with lime or lemon juice. *Gout* is a disease produced by an excess of uric acid in the blood. The fibrous structures in the neighbourhood of joints are affected. It is a disease usually of those who live on a highly nutritious diet, who drink wines or beer, and who lead indolent lives. The specific in almost all cases is wine of colchicum, in doses of 8 or 10 drops, in water, every few hours. *Rheumatism* may be acute or chronic. It is believed by some to be caused by an excess of lactic acid in the blood. What is termed rheumatic fever is a very serious disease. There is high fever, a copious flow of sour perspiration, and great pain in all the joints.

The patient is liable to suffer from inflammation of the pericardium, or of the lining membrane of the heart. The treatment is complete rest, careful nursing, and light but nutritious diet. Mix 1 ounce of bicarbonate of potash in 20 ounces of water, and give of this two table-spoonfuls every three or four hours. As the heart complications are serious, a doctor should always be in attendance. Chronic rheumatism is common in all cold, damp climates. The sufferer should always wear woollen underclothing, and avoid damp. To relieve pain, the affected part may be shampooed, or rubbed with compound camphor liniment containing a little laudanum.

Name.	Period of Incubation.	Appearance of Eruption.	Character of Eruption.	Period of Crisis.	Duration of Disease.	Complications.	Special Morbid Effects.	Mortality.	Supposed Cause.
Simple Fever (Febricula).	Unknown.	......	No eruption.	5th or 6th day.	5 to 10 days.	None.	None.	No danger.	Errors in diet; over-heating.
Typhus.	3 to 9 or 10 days.	4th to 7th day.	Small dark blue spots; often absent; do not fade away during disease.	13th or 14th day.	4 or 5 weeks; convalescence sometimes rapid; sometimes weakened constitution.	Inflammation of lung or of brain; failure of vital powers.	Attacks, specially the brain; wild delirium; often constipation.	1 in every 5 dies.	Active poisonous substance; overcrowding; contagious.
Typhoid, or Enteric, or Gastric.	10 to 14 days; may be much shorter.	7th or 8th day.	Rose-coloured spots, on abdomen chiefly; fade away, and new ones appear from day to day.	About the 21st day. Often sooner in children.	For 10 or 12 weeks, in severe cases, the patient is not out of danger.	Bleeding from bowels in early stage; inflammation of lungs in later stages; suppuration of glands of neck.	Ulcerative disease of Peyer's glands in bowel (see PHYSIOLOGY); diarrhœa, &c.	1 in every 5 or 6.	Specific poison produced in decomposing animal or vegetable matter, sewage gases, &c.; not very contagious; may be communicated by air, water, or milk.
Varicella, or Chicken-pox.	3 to 4 days.	2d day.	Pimples; become vesicles, little blebs of fluid, on second day.	Not known.	6 to 8 days.	None.	None.	None.	Unknown; usually in infants.
Variola, or Small-pox.	10 to 12 days.	3d day.	Pimples at first; afterwards vesicles, finally pustules, filled with yellow matter or pus.	No distinct period; if severe, secondary fever may set in about 10 or 11 days after beginning of disease.	5 or 6 weeks.	Inflammation of eyes, which may lead to blindness; inflammation of lungs.	None except those due to affection of skin or of lungs.	In unvaccinated persons 1 in 3, and in vaccinated 3 in 100 cases die.	A specific poison communicated from one person to another; origin unknown; contagious.
Rubeola, or Measles.	9 to 14 days.	4th day.	A blotched appearance in horse-shoe shaped areas, first in face.	8th or 9th day.	2 or 3 weeks.	Inflammation of the lungs.	Inflammation of mucous lining of all the air-passages; congestion of the eyes and nose, producing red, watery eyes, and running from nose.	About 4 in 10,000; greater when adults are affected, but is really a disease of childhood.	Specific poison communicated from one person to another; contagious.
Scarlatina, or Scarlet Fever.	From a few hours to a week, but not accurately defined.	2d day.	Bright scarlet rash, which fades away about the 5th day, in many cases sooner.	7th or 8th day, but often no marked crisis.	3 or 4 weeks in uncomplicated cases, but after-effects may last for several months.	Severe inflammation of the throat, leading to suffocation; extreme blood-poisoning. In later stages, disease of kidney and dropsy.	Inflammation of throat; putrid condition of the blood.	From 5 to 15 in 100; varies in different epidemics; greater in adults than in children.	Specific poison; the most contagious of all fevers.

SURGERY.

It is impossible exactly to define the boundary-line between medicine and surgery. Suffice it to say, that surgical diseases generally are those situated in parts of the body accessible to touch and to the direct application of remedies. Surgery, therefore, includes the treatment of the various injuries to which our bodies are constantly exposed in the daily occupations of life or from accidental circumstances. Most of those injuries occur when least expected, and when professional assistance is difficult to obtain. We intend, therefore, to give a few leading directions suitable for cases of emergency—not by any means with the view of superseding the legitimate practitioner, but that, in the interval which necessarily must elapse between the occurrence of the accident and the arrival of surgical assistance, the sufferer may be intelligently cared for; and that the surgeon may not, as too often happens, find his skill of no avail on his arrival, or have to use it to remedy the hurtful effects of ignorant interference. In country-houses, a medicine-chest should be kept, which should contain some laudanum, chloroform, sal-volatile, and quinine; also some styptics, as gallic acid. In the way of surgical appliances, there should be at hand some adhesive plaster, lint, and simple spermaceti ointment; also some roller bandages, three inches wide and eight yards long.

BLEEDING from wounds is either a general oozing from the surface, or from veins, when the blood flows in a continuous stream of a dark colour, or from arteries, when it is of a bright scarlet colour, and issues from the vessel in jerks. If the bleeding be very profuse, and attendance scanty, a tourniquet may be extemporised thus: A handkerchief should be passed a few times round the limb above the wound, and if the situation of the main artery be known, a pretty hard pad should be adjusted over it; the handkerchief should then be twisted sufficiently tight by means of a stick inserted between two of its turns.

In an ordinary cut, the best practice is to bring the edges together, and wrap a piece of dry lint round the part. If there be any difficulty in keeping the cut surfaces in apposition, strips of plaster should be placed across the wound at intervals, or a few stitches, also at intervals; at each stitch the thread should be cut, and its ends tied in a common knot: this is called the *interrupted suture*, and is most commonly in use among surgeons. The best dressing for a healing wound is lint soaked in tepid water, to which a few drops of carbolic acid have been added. If the surface of the wound appears soft and unhealthy, a lotion containing one grain of sulphate of zinc to an ounce of water is very useful.

BURNS AND SCALDS.—When heat is applied to the surface of the body, either through a solid or fluid medium, the injuries produced will be almost alike, and their severity in proportion to the temperature. Therefore, the directions for the treatment of scalds will be applicable also to burns. The first object, after the accident has occurred, is to relieve the suffering; and cold obtained by applying either ice or water seems in most cases to have almost a specific power in allaying pain and checking the advance of inflammation. In other cases, moderate warmth is found more efficacious, and we must be guided mainly by the sensations of the sufferer as to which of these remedies we make use of. The best local application is the Carron-oil, which derives its name from the famous ironworks, where it has been used for many years. It consists of equal parts of olive-oil and lime-water, and should be applied on linen rags or cotton-wool. Blisters may be pricked, and the contained serum allowed to trickle away, but on no account is the raised skin to be removed. The dressings should not be changed oftener than cleanliness requires; and as each portion of the old dressing is removed, it must at once be replaced with fresh, so that as little exposure as possible of the burnt surface may take place. Great care must be taken, in the treatment of a sore resulting from a burn, that the contraction of the scar does not cause distortion of the neighbouring parts.

When the clothes catch fire, the person should lie down on the floor, and roll herself, or be rolled, in the rug, table-cover, or anything sufficiently voluminous to stifle the flames; and afterwards the clothes, especially stockings, should be removed with great care, lest the cuticle should separate with them, which would materially increase the sufferings of the patient.

SPRAINS.—The ends of bones entering into the formation of joints are covered with smooth gristle or cartilage, so that their motions upon each other may be smooth and unimpeded; and to insure this object, they have between them a bag of a thin tissue, called synovial membrane, which secretes a fluid to lubricate the cartilaginous surfaces. They are bound to each other by strong white fibrous tissue, adjusted so as to keep those surfaces in their proper relations to each other, without impeding their movements. These fibrous bands are the ligaments. A sprain consists in a wrench or strain of these ligaments. The synovial membrane which is in contact with them participates in the injury, and immediately inflaming, pours its fluid into the joint, causing swelling; which, confined by the surrounding fibrous structures, gives rise to great pain and constitutional disturbance. These symptoms vary in proportion to the severity of the injury. Rest and fomentations of hot water to the joint are required.

DISLOCATIONS.—When the surfaces of the bones forming a joint are displaced, and have no longer their proper relations to each other, we have a dislocation. The appearance of the joint is altered, its movements limited, and there is intense pain. The displacement may be partial or complete; it may be obvious to the most ignorant observer, or so obscure as to puzzle the most experienced surgeon. Soon after the occurrence of the injury, swelling takes place, accompanied by an increase of pain, and the constitutional symptoms of inflammation soon make their appearance. After the swelling has come on, it is generally very difficult to detect the nature of the injury, as the prominent points of bone can no longer be traced; therefore, the sooner the surgeon is summoned the better, as the future usefulness of the limb will depend upon his treatment of it; and if dislocation has taken place, the longer its reduction is delayed, the more difficult will it be.

FRACTURES.—These are of three kinds—*simple*, when the bone is broken; *compound*, when it is

broken and a wound in the skin communicates with the fracture; *comminuted*, when it is broken into several small pieces. The symptoms are, great mobility and a grating feeling when the bones are rubbed. Directly a bone is broken, the muscles contracting, displace the fragments. Here, as in dislocation, the chief obstacle to reduction is the muscular resistance. The surgeon must place the limb in the position which relaxes the muscles acting on the broken ends, and by gentle extension, bring these again in apposition; then he must fix them by adjusting some mechanical contrivance, as a splint of wood, pasteboard, or gutta-percha, properly padded, so as not to excoriate the skin, and fasten it to the limb with a few turns of a bandage. After a bone is once set, it should not be disturbed except by the surgeon.

CHOKING.—Occasionally persons are choked by foreign bodies getting into the upper part of the throat, and so blocking up the aperture of the windpipe. Sometimes a lump of soft food which has stuck in the throat may be carried down by a draught of water. Sometimes a fish or rabbit bone scratches the lining membrane of the gullet, and leaves a distressing sensation of something sticking in the passage. The patient occasionally becomes very nervous and anxious, and makes violent attempts to get rid of it by swallowing bits of bread, drinking water, &c. Before using more severe surgical methods, the finger ought to be passed as far as it will reach, to search for the foreign body, and push it out. In all cases of choking, a surgeon should be summoned at once. If there be danger of immediate death, an opening should be made with a penknife in the middle line of the neck just below the prominence known as Adam's apple. A bit of the quill of a pen should be pushed into the opening, through which the person can breathe. After making the incision, there is a violent struggle for breath, but afterwards the person will breathe quite freely.

DROWNING.

The following are the directions given by Dr Marshall Hall, and which have been adopted, with slight modifications, by the Royal National Life-boat Institution and other humane societies. It is important to observe that this method is efficacious in still-born infants; in infants suffocated under the bed-clothes; in death from hanging, from noxious vapours, from narcotic poisons, from chloroform, from choking, strangling, &c. (1.) Treat the patient *instantly*, *on the spot*, *in the open air*, *exposing* the face and chest to the *breeze*. In order to clear the throat (2), place the patient gently on the face, with one *wrist* under the forehead. If there be breathing, wait and *watch*; if not, or if it fail, endeavour to EXCITE respiration by (3) turning the patient well and *instantly* on his side, and (4) exciting the nostrils with snuff, the throat with a feather, &c. dashing cold water on the face, &c. If there be no success, *lose not a moment*, but *instantly* IMITATE respiration by (5) replacing the patient on his face, raising and supporting the chest on a folded coat or other article of dress. (6) Turn the body very *gently on the side*, *and a little beyond*, and then *briskly* on the face, fifteen times in a minute. These measures may produce respiration, and, if not too late, life. We must then induce circulation and warmth. (7) Rub the limbs *upwards*, with *firm*, *grasping pressure* and with *energy*, using handkerchiefs, &c. so as to propel the blood along the veins to the heart; and, lastly (8), let the limbs be thus dried and warmed, and then clothed, the by-standers supplying coats, vests, &c.

Do not put the patient in a warm bath or allow him to lie always on his back. If all of the efforts above described prove unavailing in from two to five minutes, one may try another plan, called Sylvester's method. It is briefly this: Place the patient on the back on a flat surface, inclined a little upwards from the feet; raise and support the head and shoulders on a folded article of dress under the shoulder-blades. Draw forward the patient's tongue, and keep it out by a bit of tape or string tied round it. Loosen all tight clothing about the neck and chest. Loosen the braces or stays. The peculiarity of Sylvester's method consists in the mode of imitating the movements of natural breathing. Standing at the patient's head, grasp the arms just above the elbows, and draw them firmly and steadily upwards above the head, and *keep them stretched* upwards for two seconds. Thus air is drawn into the lungs. Then turn down the patient's arms, and press them gently and firmly for two seconds against the sides of the chest. Thus air is pressed out of the lungs.

POISONS.

By the word poison, we mean any substance which, when applied to the body either externally or internally, without acting mechanically, has the power of producing effects injurious to life. This definition is not strictly scientific, but it has a practical meaning which any one can understand on reading it. If a poison be swallowed, and we cannot get rid of it by emetics or the stomach-pump, we are obliged to administer other substances, which, by combining with the poison, may so alter its chemical properties as to render it innocuous. These latter remedies are called antidotes. We give a list of some of the most common poisons, arranged alphabetically for facility of reference.

ARSENIC—A corrosive mineral poison.

Symptoms.—Metallic taste; spitting, nausea, and vomiting, which is occasionally mixed with blood; fainting and great heat at the throat; severe gripings, purging, and tenesmus, the stools being deep green or black, and horribly offensive; the urine scanty, red, and often bloody; palpitation of the heart; cold sweats; itching and swelling of the body; prostration of strength; paralysis of the feet and hands; delirium; convulsions; death.

Treatment.—Evacuate the stomach by the stomach-pump, using lime-water; administer large draughts of tepid sugar and water, chalk and water, or lime-water; avoid the use of alkalies, but administer charcoal and hydrated peroxide of iron; take a tepid bath. If the fatal symptoms be averted, let the patient for a long time subsist wholly on farinaceous food and milk.

CORROSIVE SUBLIMATE (Perchloride of Mercury).—A corrosive metallic poison.

Symptoms.—An acrid metallic taste, burning throat, salivation, nausea, and vomiting of blood; diarrhœa; tenesmus; the pulse small, quick, and hard; faintings; debility; difficult respiration; cold sweats; cramps of all the members; convulsions; and death.

Treatment.—White of egg, diluted in water, given in large doses; a mixture of soap and gluten of white flour; warm bath; and to subsist upon broth, milk, and demulcent fluids entirely. The same treatment is suitable in poisoning by *verdigris*.

FUNGI—Poisonous mushrooms, acro-narcotic vegetable poisons.

Symptoms.—Nausea, vomiting, and purging; cramp of the lower extremities; convulsions; an unquenchable thirst; delirium; coma; and death. The intellect remains entire to the last moment of life.

Treatment.—Three or four grains of tartar emetic; castor-oil. After the stomach is emptied, give small doses of ether in mucilage, diluted with vinegar. The debility must be treated with quinine and port wine, if a fatal issue is to be averted.

HEMLOCK—A narcotic vegetable poison.

Symptoms.—Sickness; difficulty of respiration; great anxiety; vertigo; delirium, which often rises to maniacal frenzy; dilatation of the pupils; stupor; convulsions; and death.

Treatment.—Evacuate the stomach by 20 grains of sulphate of zinc, dissolved in an ounce of water; the affusion of cold water on the head; and administer vinegar and water.

MONKSHOOD—An acro-narcotic poison.

Symptoms.—Vomiting; heat in the throat; attempts to swallow; debility; weak action of heart; disordered vision; contracted pupil; bloody stools; collapse; generally no convulsions.

Treatment.—Evacuate the substance from the stomach, then administer freely acidulous fluids. External warmth; sinapisms. Small doses of tincture of digitalis.

NUX-VOMICA (*Strychnia*)—An acro-narcotic vegetable poison.

Symptoms.—Sensation of inebriety; vertigo; tetanic twitchings; rigidity of the limbs and arms; extreme difficulty of respiration, with excruciating pain under the breast-bone; asphyxia, and death.

Treatment.—Evacuate the stomach and bowels. Give 25 grains of a watery solution of the hydrate of chloral at once, and another dose of 25 grains in an hour if required.

OPIUM—A narcotic vegetable poison.

Symptoms.—Drowsiness and stupor, followed by delirium, pallid countenance, sighing, deep stertorous breathing, cold sweats, coma, and death. The *hydrochlorate of morphia*, one of the active principles of opium, in doses of 3 to 6 grains, causes headache, vomiting, sweats, and sometimes epileptiform convulsions.

Treatment.—Use the stomach-pump, or an emetic consisting of ℈ss of zinc. Vomiting should be kept up by irritating the throat; use an astringent infusion instead of water with the stomach-pump. Give large draughts of very strong tea or coffee, keeping awake the sufferer; a tepid bath; and dash cold water on the head, to rouse sensibility.

OXALIC ACID—A corrosive poison.

Symptoms.—Burning pain in the stomach, nausea, and severe but ineffectual efforts to vomit; great dilatation of the pupils; vertigo, convulsions, and death.

Treatment.—Administer, as soon as possible, a mixture of chalk and water, then evacuate the oxalate of lime thus formed, by exciting vomiting, by copious dilution, and irritating the fauces.

PRUSSIC OR HYDROCYANIC ACID—A sedative poison.

Symptoms.—If the dose be large, death is the immediate result; but if it does not exceed ten to twenty drops of the solution used in medicine, it is followed by stupor, nausea, faintness, loss of sight, difficult respiration, dilated pupils, small pulse, syncope, and death.

Treatment.—Chlorine water in doses of fl℥ij in fl℥j of water; chlorine, largely diluted with air, inhaled; hot brandy and water, or camphor mixture, combined with liquor ammonia; oil of turpentine; cold affusion; artificial respiration.

TARTAR EMETIC (Potassio-tartrate of Antimony).—An irritant poison.

Symptoms.—Nausea; vomiting; hiccough; burning in the pit of the stomach; small, hard pulse; syncope; difficult respiration; vertigo; insensibility to external stimulants; cramps; prostration of strength; death.

Treatment.—Dilute with tepid infusion of galls, and evacuate by the stomach-pump; give large doses of yellow cinchona bark, to excite vomiting by their bulk.

NURSING.

Nursing is a matter of the greatest importance in the treatment of the sick. Although it is impossible to frame a series of rules applicable to all cases, it will be always necessary, as far as possible, to attend to the following points: 1. *Cleanliness.*—The person of the patient, the bed, the room, and the nurse should be clean. This is often a very difficult task, but it should be resolutely undertaken. All excrements should be at once taken from the room, and cast into the closet or other receptacle. In the case of infectious diseases, the excrement should be acted on with such a disinfectant as Condy's Fluid, and, if possible, they should be buried in earth. The utensils should always have in them a few ounces of the disinfecting fluid. All soiled sheets and blankets should be removed as soon as possible, and put into boiling water. The patient should be kept dry, so as to prevent bed-sores. 2. *Ventilation.*—As far as can be, there should be a supply of fresh air. This is important in all cases, but more especially in fevers. Fresh air will be beneficial to the patient, and will also lessen risk of infection to the nurse. 3. *Quietness.*—The sick-room should be kept quiet. In many diseases, the senses and perceptive faculties are so acute that a little noise disturbs the patient. There should be no hurrying to and fro in a sick-room, no slamming of doors, or loud ringing of bells. 4. *Attention to Orders.*—The nurse is the doctor's substitute during his absence. It is his or her duty to see that the doctor's orders are carried out. The patient is to be supplied with food, drink, or medicine at the specified times. The nurse is to

keep a watchful care over the patient, noticing any changes of symptoms, and the times at which they occur, so as to be able to report them to the doctor on his visit. In emergencies, the nurse must be guided by common-sense and experience.

FORMS AND MODES OF PREPARATION OF MEDICINES.

Some medicines are prepared in a liquid, others in a solid form, according as they may be soluble or insoluble, or according to the state in which it may be desirable to administer them. In general, the more finely a substance can be divided, the more rapidly is it taken up by the system, and the more instantaneous its effect; hence, instead of administering the crude vegetable or mineral, the necessity of preparing infusions, decoctions, tinctures, and the like. Another reason for adopting such preparations is, that the active or medicinal principle of a substance may constitute but a small portion of its bulk; while the greater portion may be of no value whatever, or may be even positively detrimental. The preparation of medicines is the work of the pharmaceutical chemist.

Poultices are well-known external applications. They are described by Abernethy as of three kinds—the evaporating or local tepid bath, the greasy, and the irritating. The first is thus made: 'Scald out a basin, for you can never make a good poultice unless you have perfectly boiling water; then having put in some hot water, throw in coarsely crumbled bread, and cover it with a plate. When the bread has soaked up as much water as it will imbibe, drain off the remaining water, and there will be left a light pulp. Spread it, a third of an inch thick, on folded linen, and apply it when of the temperature of a warm bath.' The linseed-meal or greasy poultice is, on the same authority, to be made in the following manner: 'Get some linseed powder, not the common stuff, full of grit and sand. Scald out a basin; pour in some perfectly boiling water; throw in the powder, stir it round with a stick, till well incorporated; add a little more water, and a little more meal; stir again, and when it is about two-thirds of the consistence you wish it to be, beat it up with the blade of a knife till all the lumps are removed. Then take it out, lay it on a piece of soft linen, spread it the fourth of an inch thick, and as wide as will cover the whole inflamed part; put a bit of hog's-lard in the centre of it, and when it begins to melt, draw the edge of the knife lightly over, and grease the surface of the poultice.' The irritating poultice to be used in cases where a blister is unnecessary or inconvenient, is made simply of mustard and water, mixed as if for the dinner-table, and put within the folds of a piece of fine muslin, so that only the watery part, oozing through, touches the skin.

In whatever form medicinal preparations may be administered, the quantity is invariably regulated by weight or by measure. Though differing in nomenclature and mode of subdivision, both of these are based on the imperial standard of the country. Thus the imperial pound Troy is divided into ounces, drachms, scruples, and grains; and the imperial gallon into pints, fluid ounces, fluid drachms, and minims. In detail—12 ounces make one pound, 8 drachms 1 ounce, 3 scruples 1 drachm, and 20 grains 1 scruple. Again, 8 pints make 1 gallon, 20 fluid ounces 1 pint, 8 fluid drachms 1 fluid ounce, and 60 minims 1 fluid drachm. The different denominations of weights and measures are denoted in the language of prescriptions by the following signs: Pound, ℔; ounce, ℥; drachm, ʒ; Scruple, ℈; grain, gr.; gallon, C; pint, O; fluid ounce, fl℥; fluid drachm, flʒ; and minim, ♏. Medical prescriptions are generally written in Latin, which, conjoined with these signs, Roman numerals, and a large amount of contractions, gives them a very formidable and mysterious aspect. Thus, ℞ (*Recipe*) *Nitratis Potassae* gr. xv.; *Aquae destillatae* fl℥iss; *Syrupi Limonum* flʒij. *M.* (*Misce*). *Fiat haustus, ter in die sumendus*, is but the technical form of ordering the patient to 'Take fifteen grains of the nitrate of potash; one and a half fluid ounces of distilled water; and two fluid drachms of syrup of lemon. To mingle and form a drink of them, and take it three times a day.' In 1867, the Medical Council prepared for the United Kingdom a new Pharmacopœia, which is a list of authorised medicinal preparations, together with an account of the modes of preparing the various substances for use.

PRESCRIPTIONS FOR HOME USE.*

No. 1. *Saline Purgative for mild febrile affections.*—Take of sulphate of magnesia 1½ ounces, carbonate of magnesia 120 grains, and mix in 8 ounces of water. Two table-spoonfuls every three or four hours for an adult.

No. 2. *Mixture for Dyspepsia with Water-brash.*—Take of bismuth 180 grains, and of magnesia 120 grains. Beat up in 3 ounces of mucilage, and mix with 5 ounces of peppermint-water. One table-spoonful, in a little milk, after meals.

No. 3. *Acid Mixture for Dyspepsia. Also a tonic.*—Take of nitro-hydrochloric acid 1½ ounces, and of water 10 ounces. One table-spoonful three or four times a day.

No. 4. *Chalk Mixture, with astringents, for Diarrhœa.*—Take of tincture of catechu and of tincture of kino, of each 2 drachms; of tincture of opium (laudanum) 1½ drachms; and of mixture of chalk 8 ounces. Mix well. One table-spoonful as a dose for an adult, every three or four hours, is required.

No. 5. *Worm-powder for Children.*—Take of powder of jalap and of powder of scammony, of each 10 grains. Divide into six powders of equal size. One may be given occasionally to a child of between four and six years of age.

No. 6. *Tonic Iron Mixture.*—Take of citrate of iron and quinine 120 grains, and of water 8 ounces. One table-spoonful three times a day for an adult. Proportionately less for children.

No. 7. *Cough Mixture for Acute Bronchitis and Cough.*—Take of syrup of squills 2 ounces, of Ipecacuan wine 3 drachms, of compound tincture of camphor 3 drachms, and of water 8 ounces. A table-spoonful every four hours for an adult.

No. 8. *Cough Mixture for Chronic Bronchitis of Old People.*—Take of carbonate of ammonia 20 grains, of spirit of ether 3½ drachms, of compound tincture of camphor 4 drachms, of tincture of squills 4 drachms, and of infusion of senega 8 ounces. One table-spoonful every few hours.

No. 9. *Mixture for the beginning of all Febrile Attacks.*—Take of sweet spirits of nitre and of solution of acetate of ammonia, of each 2 ounces; water 8 ounces. One table-spoonful every three hours for an adult. Less for a child, according to age.

No. 10. *For Severe Pain, such as Colic.*—Take of spirit of chloroform 1 drachm, of tincture of opium 40 drops, and of peppermint-water 1½ ounces. One half immediately, and the other, if required, in an hour.

No. 11. *For bleeding from the Lungs, or Stomach, or Kidneys.*—Take of sulphate of magnesia 1½ ounces, of dilute sulphuric acid 3 drachms, and of acid infusion of roses 8 ounces. A table-spoonful every three or four hours. Doses of 8 or 12 grains of gallic acid, in water, also useful; or two lead and opium pills every four hours.

* In the absence of a doctor, if any of these prescriptions be carefully copied out, it can be made up by any qualified druggist.

CLOTHING—COSTUME.

WHETHER inhabiting a tropical, temperate, or arctic region—existing in abject barbarism, or enjoying the highest degree of civilisation and refinement, man always affects some kind of covering or decorative appendage, being instigated to this necessity by motives of defence, shelter, decorum, or vanity. From the simple head-dress and loin-cloth of the South Sea islander to the elaborate costume of the gay Parisian, the ruling principle is much the same; more rational, perhaps, in the case of the savage than in that of the individual laying claim to superior enlightenment. In obeying this clothing instinct or necessity, attention is always paid, not only to the kind and quality of the covering, but to the form and manner in which it shall be worn. Thus originates the distinction between clothing and costume—the one having reference to the fitness of the material for the purposes of shelter or protection, the other having reference to taste or a sense of the becoming, though often marred by the absurdities of vanity and caprice.

CLOTHING.

Admitting the above distinction, and laying aside consideration of all dress or armour of a defensive kind, clothing must be regarded simply in the light of a protection from the extremes of heat and cold, so that the body may perform its functions healthfully and without obstruction. Keeping this purpose in view, and also bearing in mind the nature and action of the human skin (see No. 8), 'it is easy to deduce that clothing should be of such a nature as not to impede the necessary escape of perspirable matter, but to suffer it to pass through its texture; that it should be of such a non-conducting quality as to confine the heat generated by the blood sufficiently to preserve the activity of the nervous system; and that, by its lightness, softness, and pliancy, it should permit the free motion of the limbs.' Clothing which would subserve all these purposes would be nearly perfect in its hygienic properties; and such an attire we could readily assume, were it not that considerations of economy, special avocations, and the like, are always interfering less or more to disturb the equilibrium. With these preliminary remarks, and referring the reader for further information on the general hygiène of dress to the article PRESERVATION OF HEALTH, we shall now consider the peculiar characteristics of British clothing.

QUALITY OF CLOTHING.

Woollen fabrics, as articles of clothing, have several advantages over other materials. They are bad conductors of heat; hence their warmth, by preventing the heat of the body from escaping, and their utility in preserving the equability of its temperature, though exposed to sudden changes. From their filamentous texture and elasticity, they are light and pliable; and yet, from their peculiar property of being *felted*, they can be prepared to any degree of weight and thickness. They possess also the property of not being easily wetted, while they are sufficiently porous either to absorb or to permit the escape of all cutaneous exhalations. Further, when worn next the skin, their rough and uneven surface produces in every motion of the body a gentle friction, which greatly assists and promotes the functions of the minute cutaneous vessels and nerves. 'In a climate like ours, which is so variable, and usually so cold, the article of dress that is worn next the skin ought always,' says Dr Robertson of Buxton, 'to be a bad conductor of heat, at all events. In general, flannel of an adjusted degree of thickness and fineness answers this intention sufficiently well,

without proving to be too heating, or irritating, or relaxing. In summer-time, if the flannel which proved to be well borne in the colder seasons of the year should be so far irritating and heating as to relax or fever the system, this may be remedied by substituting for it a thinner and finer quality of flannel; or, in extreme cases of this kind, an under-garment of calico, of a proper degree of thickness, may be substituted for the flannel at that season of the year.' The use of chamois leather as the under-garment is objectionable.

But, strongly as the importance of having a bad conductor of heat next the skin should be impressed on the mind, there is a point connected with it which is almost as important. Flannel ought not to be worn during night next the skin. In bed, it is worse than unnecessary, for it does harm: it then stimulates the skin, and produces a preternatural waste of the secretions, and corresponding debility of system—a corresponding liability to suffer from the depressing influence of cold—a corresponding incapability of resisting its influence. Dr Kilgour, in his *Lectures on Therapeutics and Hygiène*, says 'that the use of flannel was found to be beneficial in the prevention of cholera, by maintaining the equilibrium of the temperature and the functions of the skin, and thereby preventing that derangement of the bowels which is so general a consequence of cold applied to the surface.'

Cotton, though greatly inferior, ranks next to wool in non-conducting properties. From its comparative cheapness, lightness, and the facility with which it can be cleaned, it has of late years been gradually superseding the use of flannel as an underclothing. But, though recommending itself for these reasons, it can by no means be considered as a perfect substitute for flannel, either in temperate or in tropical climates, whether used in a pure state or when mixed with a certain proportion of wool.

Linen, though inferior both to cotton and wool as a non-conductor of heat, and as becoming more readily wet, is now extensively used as an article of inner clothing. It has drawbacks for this purpose, however, arising from its being a good conductor of heat. It rapidly robs the skin of its free caloric; hence the cold feeling experienced when linen is just put on. But though rapidly conducting the heat, it has little capacity for moisture, and thus soon becomes saturated, leaving the pores of the skin clogged and obstructed, unless the garment be frequently changed. Having little elasticity of fibre, it forms a smooth and dense fabric, totally void of that stimulating function often so much valued in flannel. From the experiments of Count Rumford, it appears that linen does not attract dampness so readily as wool, hair, or other animal substances; nevertheless, when it is damp, it is more prejudicial than these, and therefore requires to be well dried and aired before being worn.

Silk, as a non-conductor of heat, ranks next to cotton; but its qualities in this respect depend in a great measure upon the kind of fabric into which it is woven. Generally speaking, silken fabrics are light and thin; articles of luxury and ornament rather than of everyday utility. Nevertheless, silk possesses several valuable hygienic properties, of which the most curious and least understood is that appertaining to its electric qualities. It is found (see No. 17) that on the whole the state of the body when healthy and vigorous is *positive*, or that a surplus of positive electricity tends always to appear on the surface, from the actions of the vital organs; but that, after severe labour, hard exercise, and exhaustion, the state of the free electricity generally changes to *negative*. It is not improbable that when the actions of electricity on the animal system are better understood, it may be possible to use artificial methods of maintaining, under all circumstances, the charge that is identical with health and activity: we have acquired, by means of our houses, clothing, and fires, a tolerable command of the element of heat; and it is to be hoped that we may some day attain an equal command over the element of electricity, and keep at a distance the deleterious negative charge as effectually as we defy the winter cold. On this important subject, so far as the influence of silk—which is an excellent non-conductor of electricity—is concerned, Drs Robertson and Carpenter have the following interesting remarks, which we transcribe at length:

'However little or unsatisfactory our knowledge of the operations of this remarkable agent in the animal economy, there is no doubt that electricity fulfils important and necessary purposes in the living system, and that a certain amount of positive or negative electricity is being constantly given off from the surface of the body in greater or less degree, according to sex, temperament, weather, the nature of the clothing, &c. It has been said that the skin and most of the internal membranes are in opposite electrical conditions; and, according to a theory of Dr Wollaston, the existence of free acid in the urine and gastric juice marks the prevalence of positive electricity in the kidneys and the stomach; whereas the existence of free alkali in the bile and the saliva indicates an excess of negative electricity in the liver and the salivary glands. Whether this view be tenable or not, it seems that the living body is never in a state of perfect electrical equilibrium with the substances or bodies around it, unless it be maintained by free contact with them; and it is stated, in illustration of this, that if two persons, both insulated, join hands, sufficient electricity is developed to influence the electrometer. Some electric disturbance is manifested by almost every individual, if it be carefully sought for. In men, it is most frequently positive; and irritable men, of sanguine temperament, have more free electricity than those of phlegmatic character; whilst the electricity of women is more frequently negative than that of men. Some individuals exhibit these phenomena much more frequently and powerfully than others. There are persons, for instance, who scarcely ever pull off articles of dress which have been worn next the skin without sparks and a crackling noise being produced, especially in dry weather; this may, however, be partly due to the friction of these materials on the surface, and with each other, as it has been proved to be greatly influenced by their nature.

'The most remarkable case of the generation of electricity in the human subject at present on record, is one that has been met with in America (*American Journal of Medical Science*, January 1838). The subject of it, a lady, was for many months in an electric state so different from that

of the surrounding bodies, that whenever she was but slightly insulated by a carpet, or other feebly conducting medium, sparks passed between her person and any object which she approached. From the pain which accompanied the passage of the sparks, her condition was a source of much discomfort to her; when most favourably circumstanced, four sparks per minute would pass from her finger to the brass ball of the stove, at the distance of one and a half inch. The circumstances which appeared most favourable to the generation of electricity, were an atmosphere of about eighty degrees, tranquillity of mind, and social enjoyment; while a low temperature and depressing emotions diminished it in a corresponding degree. The phenomenon was first noticed during the occurrence of an aurora borealis; and though its first appearance was sudden, its departure was gradual. Various experiments were made, with the view of ascertaining if the electricity was generated by the friction of the articles of dress; but no change in these seemed to modify its intensity. It was no doubt generated, or the electrical equilibrium was disturbed in an undue and very extraordinary degree, by the condition of the nervous system, probably influenced by some deranged condition of certain of the organic functions. It seems to have been proved that electrical manifestations are the invariable consequence of the action of the nerves in producing muscular action; and it is probable that this powerful agency of electricity exercises an important influence on the digestive processes, and perhaps especially in facilitating the decomposition of the food, and so far preparing it to enter into new combinations for the nutrition of the body. But however this may be, and however large, or little important, the influence of electricity may be in carrying on the vital and organic processes of the system, there is no doubt that a certain amount of electrical matter is constantly being given off from the surface of the living body; that the amount of this varies according to the dryness or dampness, the coldness or warmth, of the atmosphere; and that the degree to which it is permitted to escape may be influenced by the nature of the clothes, and particularly according to the nature of the fabric which is worn next the skin; and that the escape of this electricity is so far attended with diminished power and energy of the general economy, and in the same degree to which such escape may be prevented, is the system maintained in a state of more vigorous vitality. The depressing influence of wet and cold weather may be largely referred to the effect of such an atmosphere in carrying off rapidly the free electricity of the system; and the colder and more damp the climate man lives in, the more important is it that he surround the body with such articles of clothing as will check, as far as may be, the escape of this extraordinary agent; and the greater the habitual depression and debility of the economy, the less the degree of its vital energy, the more important does this consideration become.

'Silk, as a remarkable non-conductor of electricity, deserves to be made use of more generally than it is in this country, as an article of under-clothing. For this purpose, it should be woven entirely of what is called *bright* or *wrought* silk, in contradistinction to what is called *spun* or *spurious* silk; and the under-garment is to be manufactured in a similar way, and of a similar material, to stockings, but woven with much thicker thread into a very thick and heavy fabric.'

Furs and *down* are by far the warmest materials, but in Britain they can scarcely be considered as articles of general clothing. Soft, light, elastic, they constitute excellent adjuncts during the winter months, while their fine colours and markings add greatly to their appearance. When worn as furs usually are, with the skin attached, they are rather impermeable to exhalations, and are not in this light to be considered as equal to the finer fabrics woven or knitted from wool. *Leather*, unless peculiarly prepared (as chamois), is by no means fit to be worn as an inner garment, and even then its use is not to be commended. In fact, the common application of this material is for boots and shoes, for which it is admirably suited by its strength and durability. When well manufactured, leather should be soft and pliable; and when fashioned into shoes, these should be rather large and easy. There is, in general, no member of the body more sinned against—the chests of stay-wearing ladies scarcely excepted—than the foot; and the certain penalty is corns, callosities, and deformities, an unspeakable amount of pain, and in the long-run, a partial destruction of the powers and functions of one of the most essential of the bodily organs. The feet, with proper treatment, ought to be as free from disease and pain as the hands, their structure and adaptation to the wants and comforts of man being naturally perfect. 'Thirty-six bones and thirty-six joints,' says a writer on the Foot, 'have been given by the Creator to form one of these members, and yet man cramps, cabins, and confines this beautiful arrangement of 144 bones and joints—together with muscles, elastic cartilage, lubricating oily fluid, veins, and arteries—into a pair of boots or shoes, which, instead of forming a protection, produces the most painful and permanent injuries.' These objections as to room cannot be urged with the same force against the numerous *elastic fabrics* now coming into use, as these, to a certain degree, expand and contract according to the requirements of the foot; but then there is this objection—all of them are impermeable to perspiration. The foot while heated perspires, the moisture is not allowed to exhale, and on resuming a state of rest, cold and damp is the result. This objection, indeed, is fatal to all the elastic *waterproof fabrics* now so much in vogue: the insensible perspiration must be absorbed or exhaled, and if not, discomfort and disease are the inevitable consequences. Numerous ingenious attempts have been made to remedy these defects, so as to retain the other valuable properties of elastic and waterproof clothing; but as yet we have seen none completely successful; and for our own parts, we would rather undergo a drenching, which can be laid aside with the garment which sustains it, than sit for hours enveloped in offensive exhalations.

AMOUNT OF CLOTHING.

1. Although it is proper to adapt our clothing to the temperature, change must be made with caution. The animal constitution is no doubt endowed with considerable plasticity; but that plasticity must be operated upon by insensible gradations. A well-fed man has a source of heat

within him; and food may be said to supplement clothing, and clothing food. If we lose heat through lack of clothing, the food must supply it; and *vice versâ.* 2. The young and vigorous, other things being equal, require less clothing than the old and infirm. While the respiration and circulation of the system is vigorous, and the diet wholesome and full, every function is performed with activity; heat is freely formed; and the exercise generally taken by the young greatly augments the supply. But the young and vigorous must not neglect the ordinary rules of clothing on this account—a neglect they are but too apt to perpetrate, and which, in the case of infancy, is too often perpetrated against them by ignorant nurses, and equally ignorant and foolish mammas. 'Are the little "Highlanders,"' asks Dr Erasmus Wilson, 'whom we meet during three out of the four quarters of the year under the guardianship of their nursery-maids, dawdling about the streets in our public walks or squares, properly protected from the cold? Are the fantastically attired children whom we see "taking an airing" in carriages in our parks, sufficiently and properly clad? If these questions can be truly answered in the affirmative, then, and then only, my remarks are needless. There can enter into the parent mind no more baneful idea than that of rendering children "hardy" by exposing them unnecessarily to cold, and by clothing them inefficiently. The little denizens of a warm nursery must not be subjected, without a carefully assorted covering, to the piercing and relentless east or north-east wind; they must not be permitted to imbibe the seeds of that dreadful scourge of this climate—consumption—in their walks for exercise and health; they must be tended, as the future lords of the earth, with jealous care and judicious zeal. *One-sixth of the deaths of young children*, it must be remembered, *result from cold.*' 'The large mortality,' says another medical authority, 'among the children of the poor is to be referred to an undue exposure of their feebly acting and sensitive surfaces to the influence of the cold.' It by no means follows, however, from what has been said, that the systems of the young are to be overheated, relaxed, and enfeebled by an excessive amount of clothing, an amount disproportioned to the requirements of health and growth.

As to special articles of dress, and the clothing of special parts of the body, there is often injudicious management, partly from mistaken physiological notions, and partly from caprice and fashion. Thus there is nothing more common than to dress heavily when we go out of doors, and put on some thin flimsy covering within doors; to clothe well during one portion of the day, and be in loose, open, undress during another. Such sudden changes are contrary to all reason, and cannot fail to be prejudicial to sound health and comfort. The human body is not a piece of mechanism, which can be wound up and adjusted at pleasure; and far less is it to be tampered with in direct opposition to the natural laws under which it is constituted. What more preposterous than to dress heavily when under the warming influence of exercise, and to dress loosely and lightly when sedentary, and when all the functions of circulation and respiration are languid and slow! Another error, very common in this country, is the inordinate wrapping of the neck and shoulders with kerchiefs, shawls, and furs. To behold men and women, old and young, all be-muffled and be-boa'd, no matter what the day or what the occasion, a stranger would be apt to imagine the country labouring under one huge epidemic; and yet the truth might be some absurdity of fashion—some monkey imitation of A by B, C, D, and all the other letters of the alphabet. 'Unless when much or unusually exposed to the influence of cold,' says a high medical authority, 'the risk of local relaxation from this practice, and of an unadvisable degree of chill when such extra clothing is removed, deserve consideration, and may lead to greater evils than such extra wrapping is calculated to obviate. It is only justifiable under circumstances of extreme and long-continued exposure to cold, or in the instance of very delicate and susceptible systems.'

Another instance in which very irrational and often fatal errors are committed, is in not duly protecting the feet. 'Of all parts of the body,' says the same authority, 'there is not one the clothing of which ought to be so carefully attended to as the feet. The most dependent part of the system, this is the part in which the circulation of the blood may be the most readily checked; the part most exposed to cold and wet, or to direct contact with good conducting surfaces, it is the part of the system where such a check is most likely to take place. Coldness of the feet is a very common attendant on a disordered state of the stomach; and yet disordered stomach is not more apt to produce coldness of feet, than coldness of feet is apt to produce disorder of the stomach; and this remark does not apply only to cases of indigestion, but to many other disorders to which man is liable. Yet do we see the feet of the young and delicate clad in thin-soled shoes and as thin stockings; no matter whether the weather is dry or damp, or whether the temperature of the atmosphere is warm or cold. But this is not the whole of the evil. These same feet are frequently, at different times of the day, differently covered as to stoutness of the shoes and their soles, and very often likewise as to the thickness of the stockings. . . . I am sufficient of a Goth to wish to see thin-soled shoes altogether disused as articles of dress; and I would have them replaced by shoes having a moderate thickness of sole, with a thin layer of cork or felt placed within the shoe, over the sole, or next to the foot. Cork is a very bad conductor of heat, and is therefore to be preferred. Its extreme lightness, the remarkable thinness to which it may be cut, its usefulness as a non-conductor not being greatly impaired thereby, and the inappreciable effect it has on the appearance of the shoe, all seem to recommend its use for this purpose in the strongest manner.'

Among the special instances of error as to the amount of clothing, the writer just quoted places pre-eminently that of bed-clothes. In Britain, where a great variety of material is used—such as feathers, down, hair, woollen blankets, cotton counterpanes, and linen sheets—this subject is deserving of more attention than it generally receives; and all the more seeing that while in bed the skin usually throws off much more of its secretions than at other times. What is required is a mere sufficiency to keep the surface warm;

everything beyond this is exhausting and detrimental. What is sought for in bed is rest of mind and body; and this most certainly cannot be obtained when half-smothered, heated, and irritated by an undue amount of warm clothing. 'A free and sufficient use of exercise, and particularly walking-exercise; a regular exposure to the open air; a daily change of air, as far as may be practicable—walking as far away from home as strength, and time, and weather allow, instead of confining the exercise to a circle near the house; and a regulated diet, are the great means, next to sufficiently frequent ablutions, of keeping the vessels of the skin in a state of efficient activity, and preserving or restoring the natural temperature of the surface. And this point having been gained, very few and light bed-clothes are all that will be required.'

COSTUME.

Dress may be said to consist of three generic forms—the simple attire of savage life, in which a skin, blanket, or some other loose covering, is nearly all that is employed; the flowing and elegant dress of the East; and the precise and more closely fitting clothing of modern European nations. Of the first mentioned, little need be said. In the absence of manufactured articles, savage tribes in all countries are, and have been, in the habit of attiring themselves in such rude materials as nature has placed within their reach. The Indian of North America clothes himself in skins on which the fur is left, or with a blanket procured from the wandering trader. His legs and feet he dresses in moccasins made from a species of leather, and in full dress he fancifully paints his skin with pigments. In some of the islands of the Pacific—as also till lately in New Zealand—the inhabitants *tattoo* the surface of the body, by puncturing it with an instrument, and inserting coloured juices in the wounds. Such, likewise, was the barbarous practice and fashion of the original inhabitants of the British Islands.

North American Indian.

Throughout Asia, in North Africa, and in Turkey, the dress is generally of a loose and flowing form, that of the common people in China being least so. The *turban* is almost universal. It is a male head-dress, composed of muslin swathed in folds, for the most part round a cap; and by presenting a mass of light material to the sun, it is considered to be a suitable covering for the head in Eastern climes. The forms of this head-dress, however, differ considerably, some being more tasteful than others. The first represented in the preceding figure is the round turban common in Africa; the second, an elegant modern Egyptian form.

A crowd in Constantinople, previous to the late modifications of costume, was, says a traveller, a picturesque group: 'there was the graceful Effendi Turk with snow-white turban, jetty beard, sparkling and full eyes, long flowing caftan, scarlet trousers, yellow boots, rich Cashmere shawl round the waist, in which shone the gilded dagger; next was the gay but cunning-looking Greek, with short chin, black turban, enormous but short trousers, bare legs, and black shoes; then the grave Armenian, with his calpac of black felt balloon-like upon his head, his long Turkish robe, silver ink-horn in his girdle, and his feet in the crimson slipper or boot; next was the Jew, with his blue turban and slippers; and with these were seen the high taper calpac of the Tartar, the melon-shaped head-piece of the Nizam Djedid, the gray felt conical cap of the imam and dervish, and occasionally the ungraceful hat of the Frank, with the be-buttoned and mean-looking costume of Western Europe.'

The dress of the modern Greeks is a mixture of Eastern and European costume, with little to mark the classical origin of the peopl . The chief article of attire of the poorer Greeks is a *capote*, or large woollen garment, with a hood, shaggy with short threads of yarn; it is heavy when dry, but nearly insupportable when wet; it is as serviceable for home and bed to the wandering Greek as the *bunda* is to the Hungarian shepherd, and it is a perfect defence against cold and dew. All but the poor classes of Greeks, however, dress showily, and even a servant will expend every farthing of his wages in fine clothes. Thus a physician's janizary may be seen in a rich robe of scarlet, his vest of blue velvet trimmed with gold-lace, and in his silk girdle a brace of pistols embossed with silver; turban, short petticoats, and trousers of purest white, and gaiters or leggings of scarlet velvet embroidered with gold; altogether, a costume that might suit a prince. The general dress consists of a short embroidered jacket, without collar, and with sleeves open from the elbow; an embroidered vest, a cotton shirt, a tunic of several folds, secured by a sash or shawl about the waist, and reaching to the knee; loose breeches or trousers, short socks, and slippers between sandals and shoes. In one corner of the sash, the common people carry their money, which the rich put into purses, and carry, with their handkerchiefs, watches, and snuff-boxes, in their bosoms. The head-dress is various—as the turban, *à la Turque*; the fur-cap, like a muff; the fez or tasselled cloth cap, worn on one side; the plain caps of the peasantry; and skull-caps of

The Greek.

velvet or gold, embroidered and tasselled. The young Greeks are the handsomest race in Europe; their long hair falls over their shoulders from under the cap; their embroidered jackets, vests, and buskins, their arms mounted with silver and even jewels, and their white kilts, compose, on the whole, one of the most graceful and becoming costumes in the world.

The costume of the Greek female closely resembles that of the Turks. She wears loose trousers of fine calico, embroidered with flowers, a closely fitting vest, a jewelled zone about the waist, and a long-sleeved gown, flowing off loosely behind, or a veil covering the body; and sometimes a rich pelisse trimmed with fur. Jewellery is worn to excess; and bracelets of gems, or strings of gold coins round the arm and neck, across the forehead, and in the hair, which the younger girls let fall down their backs and over their brows and cheeks. Little caps, similar to those of the men, are also worn by the females, studded with coins, but worn on one side of the crown, the girls wearing in them flowers, and the matrons, heron-plumes or jewels. The young women often dye their hair auburn, and the old ladies red, with which colour the nails are also tinged. The females walk abroad in a robe of red or blue cloth, and an ample muslin veil.

The dress of modern Europe, and, we may add, that of civilised America, differs little in essentials. With few exceptions, it is well fitted for an active, hard-working, city-dwelling people; it has little cumbrous or unnecessary about it, and if not always so graceful or picturesque as could be wished, it is free at least from the reproach of 'barbaric pomp and ornament.' Climate, business vocations, and conventional usages, require it to be somewhat precise; but this precision can never become ridiculous unless through what the gay world denominates *fashion*. The usual notions concerning flowing or classical costume are traditionary and irrational; for if there be anything 'divine' in the human form, the less that any costume cumbers, and conceals it—consistently with comfort and decorum—the more becoming must it of necessity be. We devote the remaining pages to the history and development of

BRITISH COSTUME.

Partly from a wider acquaintance with other countries, partly from the introduction of new pursuits and vocations, and partly from caprice and fashion, the costume of our country has undergone many changes in the course of ages. Among the Southern Britons, at the time when Julius Cæsar landed in the country (55 B.C.), the arts connected with clothing had made some advance; but in the more northern parts, the practice of living half-naked, with painted and tattooed bodies, was common, and, notwithstanding the severity of climate, remained till a much later period. Such fanciful decorations are supposed to have given name to the nation of *Picts* (from the Latin word *picti*, painted); corresponding to their Celtic designation of *cruithne*.

Pict.

The usual Roman dress, in the latter period of the Empire, consisted of a tunic, or loose upper garment, with a dress for the lower limbs, called *braccæ;* hence the modern term *breeches*. Over all was occasionally worn by the higher classes the *toga*, or mantle. It is believed that these Roman costumes were generally copied by the greater number of British, at least among the more opulent classes. In the dress of the women, however, there was but little change. They appear in two tunics, the one reaching to the ankles, the other having short sleeves, and reaching about half-way down the thigh: in other words, they resemble a round gown, or bedgown and petticoat, though the latter, distinct from a body and sleeves, is not considered to be ancient. This tunic was called in British *gwn;* hence our word *gown*, of which we still see specimens of short dimensions worn by women of the humbler classes in England, Scotland, and Wales.

Anglo-Saxon and Danish Periods.

The Anglo-Saxon and Danish periods of English history are marked by new peculiarities in costume. Soon after the departure of the Romans and the arrival of the Saxons in 449, fashions of apparel were introduced from Northern Germany, which were copied by the Romanised British, and continued with no material change for several centuries.

The most important improvement in the ordinary dress of the people was the introduction of the *shirt*, a linen garment worn next the skin, for which we are indebted to the Saxon invaders. The common dress of the eighth century consisted, as we find, of linen shirts; tunics, or a kind of surcoat; cloaks fastened on the breast or shoulders with brooches; short drawers met by hose, over which were worn bands of cloth, linen, or leather, in diagonal crossings. Leathern sandals were worn by the early Anglo-Saxons; but afterwards the shoe became common: it was very simple, and well contrived for comfort, being opened down the instep, and there, by a thong passed through holes on each side of the slit, drawn tight round the feet like a purse. A felt or woollen cap, called *haet* (hence our modern word hat), was worn by the higher class of Anglo-Saxons; but it is generally believed that the serfs or lower orders were without any other covering for the head than what nature had given them.

Although Sir Walter Scott disclaims pretension to complete accuracy in the costume of the characters in his historical romances, the following portrait of Gurth, the Saxon swine-herd, in *Ivanhoe*, is nearly correct: 'His garment was of the simplest form imaginable, being a close jacket with sleeves, composed of the tanned skin of some animal, on which the hair had been originally left, but which had been worn off in so many places that it would have been difficult to distinguish from the patches that remained to what creature the fur had belonged. This primeval vestment reached from the throat to the knee, and served at once all the purposes of body-clothing. There was no wider opening at the collar than was necessary to

admit the passage of the head, from which it may be inferred that it was put on by slipping it over the head and shoulders, in the manner of a modern shirt or ancient hauberk. Sandals, bound with thongs made of boar's hide, protected the feet; and a sort of roll of thin leather was bound artificially round the legs, and, ascending above the calf, left the knees bare, like those of a Scotch Highlander. To make the jacket sit more closely to the body, it was gathered at the middle by a broad leathern belt, secured by a brass buckle, to one side of which was attached a sort of scrip, and to the other a ram's horn, accoutred with a mouthpiece for the purpose of blowing. In the same belt was stuck one of those long, broad, sharp-pointed, and two-edged knives which were fabricated in the neighbourhood, and bore even at this early period the name of a Sheffield whittle. The man had no covering upon his head, which was only defended by his own thick hair matted and twisted together. One part of his dress only remains, but it is too remarkable to be suppressed: it was a brass ring resembling a dog's collar, but without any opening, and soldered fast round his neck; so loose as to form no impediment to his breathing, yet so tight as to be incapable of being removed, excepting by the use of the file. On this singular gorget was engraved, in Saxon characters—"Gurth, the son of Beowulf, is the born thrall of Cedric of Rotherwood."'

Anglo-Saxon Serf.

The Anglo-Saxon females wore under-tunics, with sleeves; another inner garment—the linen kirtle; and over these the long full gown, with loose sleeves. The head-dress was a hood or veil, which, falling down before, was wrapped round the neck and breast; and this was the only head-covering of the women when abroad. The hair was carefully dressed, and golden head-bands, half-circles, neck-bands, and bracelets were worn; with ear-rings, necklaces, crosses, and jewelled ornaments too numerous to describe. The hose and shoes resembled those worn by the men. The long sleeves of the gown or the mantle, drawn over the hands, served as gloves, which were not worn before the eleventh century. All classes used on their cheeks a red cosmetic, so that the art of painting the face is not the creature of refinement. The general colours of the dresses were red, blue, and green, sometimes embroidered in patterns; and gold tissue and cloth of gold were worn by princesses and nuns; and the latter embroidered robes, sandals, tunics, vests, cloaks, and veils of enormous cost—for pearls and precious jewels were interwrought with the materials, and sometimes three years were spent in working one garment; and their dresses were often lined with sable, beaver, and fox furs, or the skins of lambs or cats.

In the article of dress, the Danish intruders into Britain were, after a time, equally profuse. The Anglo-Danish kings appear principally to have worn a red habit, embroidered with gold, and a purple robe; and their mantles were richly embroidered with gold and pearls. Upon a manuscript of the reign of Canute, that monarch is, however, represented in a Saxon dress, the mantle being richly ornamented with cords or ribbons and tassels; and he wears shoes and stockings with embroidered tops. His body, when discovered in Winchester Cathedral in the year 1766, was decorated with gold and silver bands, and a richly jewelled ring; bracelets were worn by all persons of rank, and invariably buried with them. Canute's queen wore the tunic, mantle, and long veil. The materials of the Danish dresses were cloths, silks, or velvets, procured either from Spain or the Mediterranean, by plundering the Moors.

From the Danish invasion to the Norman Conquest there were few changes in costume, if we except the imitation of Norman-French fashions in the reign of the Confessor, by shortening the tunics, clipping the hair, and shaving the beard, but leaving the upper lip unshorn. Tattooing after the Pictish fashion was practised even to this time, although it had been forbidden by a law passed in the eighth century.

Eleventh till Fourteenth Century.

The Norman Conquest introduced a greater degree of taste and splendour into British costume; but the dress of the common order of people remained long of a comparatively rude fashion, partly from the effect of caste and sumptuary laws, which prevented any decided change. As time advanced, the materials of dress improved, but the fashioning was little different, and, till this day, we have a sample of the Anglo-Saxon tunic in the *smock-frock*, a species of overall linen shirt, very generally worn by the peasantry of England. The *blouse*, a coarse linen shirt of blue instead of white, which is now universally worn by workmen in France, Switzerland, the Low Countries, and part of Germany, had an equally early origin.

In the reign of Rufus many costly changes were made in dress; the tunics were lengthened, and the under garments even trailed upon the ground. The sleeves were also drawn over the whole hand, although gloves were worn, at least by the higher classes. The cloth mantles were lined with rich furs; and one lined with black sables and white spots cost £100. Extravagantly peaked-toed boots and shoes were worn; and a court coxcomb, who caused the points of his shoes to curl like a ram's horn, received the name of *De Cornibus*, or 'with the horns.' The hair, which had been shorn from the back of the head as well as the face by the Norman-French, was now again worn long; and the courtiers in Stephen's reign even wore artificial hair, so that wigs may date from the twelfth century. The long beard also reappeared in the reign of Henry I. (1100-1135).

About this period, *gloves*, highly ornamented, appear to have been used by kings and the higher church dignitaries. Gloves, or a clothing of leather for the hands, had not been unknown in early ages; by the Greeks and Romans they were employed as a protection in certain kinds of rough labour. Now they were employed as part of a mailed dress, and also on ceremonial occasions. From the monumental effigy of Richard I. it is seen that he wore gloves ornamented with jewels

on the back of the hand. Throwing down a glove became a challenge of defiance to single combat, according to the etiquette of these partially barbarous ages. From being worn only by kings, archbishops, courtiers, and knights, gloves made of various materials gradually became a portion of ordinary dress.

In the course of the thirteenth century, the sumptuousness of apparel increased; rich silks woven with gold, embroidered and fringed, and French velvets, were much used; and a rich stuff manufactured in the Cyclades was made into a dalmatica or super-tunic, called Cyclas, which was worn by both sexes. The furs of ermines, martens, squirrels, the vair, and the minevair or minever, were added to the list of furs for winter garments.

The general male dress consisted of the cyclas just mentioned, and the tunic; but the principal novelty is the super-totus, or overall, worn like the mantle or cloak, and consisting of a kind of large-sleeved shirt, with a capuchon. Long-toed shoes and boots were resumed, with embroidery and colours.

The female costume differed in fashion and name, rather than in form, from that of the twelfth century. The veils were of gold tissue or superbly embroidered silk, and over them was worn a diadem, circlet, or garland, or a caplike coronet, by persons of rank, and sometimes a round hat. The head-dresses were very numerous. The wimple covered the head and shoulders, and was fastened under the chin; and the hair was worn in a net or caul of gold-thread, which continued in fashion for the next two centuries. A very ugly kind of wimple, called the gorget, appeared in the thirteenth century; it was a neck-covering, poked up by pins above the ears. The long robe was also worn trailing on the ground; the cloth stockings were embroidered with gold; and trinkets of gold, as buckles, rings, ear-rings, and chaplets, and jewels, were much worn. In this century, too, we first meet with the surcol, which Strutt calls a corset, bodice, or stays, worn over the rest of the dress, which enlarged in the skirt, and spread into a train; it was made high in the neck, and had long tight sleeves.

The dress of the working-classes may be supposed to have been improved about this period by the introduction of the worsted manufacture: it is stated to have been brought to the country by a colony of Flemings, who in the reign of Henry II. settled at *Worsted*, a village in Norfolk; hence the name of the fabric.

Fourteenth and Fifteenth Centuries.

We now come to the fourteenth century, in which Edward III. and his queen Philippa led the fashion in apparel. As seen from the effigy on his tomb, the costume of Edward is characterised by its dignified simplicity. The dalmatica is low in the neck, falls in straight folds to the feet, and is open in front nearly half its height, being embroidered at the edges of the aperture; the sleeves of the under-tunic have at each wrist a row of buttons, a fashion of the reign of Edward III.; the mantle, embroidered at the edges, is worn over the shoulders, and confined by a jewelled band across the breast; the shoes or buskins are also embroidered, and the hair and beard are patriarchal; the crown has been removed or lost. The effigy of Queen Philippa, also at Westminster, is equally distinguished by its simplicity; the skirt is long and full, the bodice closely fitting, the waist-belt jewelled, and the mantle ornamented on the shoulders, and confined by a diagonal band across the breast; and upon the head is a low crown, jewelled, and from it depends a kind of draped ornament half-way down the cheek. The costume of the nobles in this reign was, however, far less simple than that of the sovereign. In place of the long robe and tunic, was worn a close-fitting body-garment (jupon), superbly embroidered, reaching to the middle of the thigh, and confined across the hips by a splendid belt; from the sleeves of this garment hung long slips of cloth, called *tirippes* (tippets); and over the whole was occasionally worn a long mantle, fastened by buttons upon the right shoulder. This dress was, however, the extreme of foppery. The caps were of various shapes, and among them we find the knight's *chapeau*, nearly in the form now used in heraldry. Beaver hats were also worn; but the greatest novelty was a single feather in the front of the cap. The golden chaplets, by the addition of leaves, now assumed the form of coronets. The gay tournaments of this period led to the introduction of many costly foreign fashions; so that, in 1363, expensive dress, beyond the income or rank of the wearer, was forbidden by law; furs of ermine and pearl ornaments (except for head-dress) were forbidden to all but the royal family and the wealthiest nobles; cloths of gold and silver were permitted only to the next in fortune; and persons of small income were forbidden to wear silks, embroidery, or trinkets. But the ladies dressed still more sumptuously, as in the engraving, where the gown fits close in the bodice, and the train is so long in the front as to be held up, and thus display the embroidered under-dress; the sleeveless jacket worn over the gown is also embroidered and trimmed with fur; the hair is worn long, and the cap is low, and resembles a coronet. Tippets from short sleeves, and the jupon, were also worn by ladies as well as by gentlemen; and both sexes wore daggers stuck through pouches in their rich girdles. In this reign, *mourning habits* appear to have been first worn, the colours being black and brown.

The reign of Richard II. must have been the high carnival of coxcombry. The sovereign himself, according to Holinshed, had a coat or robe which cost 30,000 merks. Party-coloured dresses were universally worn; and even the hose were of two colours, so as to render the term a *pair* inapplicable: the colours of the king and his court were white and red. Men and women alike wore hoods set with jewels; and their tippets were jagged, and reached to the heels; and the long-peaked shoes, called *crackowes* (from Cracow, in Poland), were fastened to the knees with gold and silver chains. The following engraving shews a gentleman of this period, with shoes and hose all in one, the mantle cut into the shape of leaves at the edges, a belt and pouch, and a fantastically turbaned head-covering. Chaucer has left us the costume of several ranks at this period: his squire wears a short gown, 'with sleeves long and wide;' his yeoman, 'a cote and hoode of grene;' his merchant, many colours, with a forked beard, and a 'Flaundrish beaver hat,' and clasped boots; the reeve or steward, a long surcoat and rusty sword, his beard and head shaven and shorn; the miller

wore a white coat and blue hood, a sword and buckler, and red-cloth holiday-hose; and the hats, caps, and bonnets of all classes were very fantastical. Knives, ornamented with silver, and purses, were worn by most classes in their girdles; and shoulder-belts, with bells, were a mark of rank.

Gentleman of Fourteenth Century.

Lady of Fourteenth Century.

Liveries are also now mentioned as worn by substantial artisans, as well as by menial servants; but the ploughman appears only in a tabard or sleeveless coat, and the mechanic in a tunic. The hair was worn long and curled, and the beard forked.

In the female costume of this reign the fantastic party-coloured dresses were retained, with the embroidered jupons and kirtles, hip-kirtles, and long tippets from the elbow; and the surcol, or external corset, faced with fur, and terminating in a train sometimes so long as to be carried over the arm, or shorter, opened up the side, and bordered with ermine. The head-dress continued as in the preceding reign. The attire of the carpenter's wife in the *Canterbury Tales*, with a silk girdle and head-fillet and brooch, indicates the condition of this class of females.

The costume of the fifteenth century was equally

Gentleman of Fifteenth Century.

Lady of Fifteenth Century.

gay and foppish, but perhaps more neat in form. The above engraving represents a gentleman of the reign of Henry V.: he is dressed in a short tunic, buttoned in front, with girdle, large loose sleeves, tight hose, forming pantaloons and stockings in a single piece, peaked shoes, and head-cloth or cap. About this period, silks and velvets of divers colours came into use among the higher classes, by whom gold chains were generally worn. The dress of ladies was of the richest kind. Gowns were embroidered and bordered with furs or velvet; and the bodice, laced in front over a stomacher, now first appeared. But the greatest eccentricity was the lofty steeple head-dress, shewn in the annexed portrait; this consisted of a roll of linen, covered with fine lawn, which hung to the ground, or was mostly tucked under the arm.

Richard III. (1483-1485), according to his wardrober's books, was a right royal fop, for we find him wearing a blue cloth-of-gold doublet and stomacher, 'wroght with netts and pyne-apples,' and crimson and purple-velvet robes, embroidered and furred, and crimson satin hose, and tissue cloth-of-gold shoes, at his coronation. The nobles in this reign had their hose tied by points to the doublet, which was sometimes worn open, but laced like a bodice; and over it was worn a long or short gown, the former hanging loose, and the latter plaited before and behind, and girded about the waist; and both gown and doublet were slashed. The general head-dress was a closely fitting cap or *bonet* (bonnet), with a single feather in it; and scarlet hats and hoods were worn. The boots had very long-pointed toes, and reached to the middle of the thigh.

Hitherto, the authorities for costume have been illuminated manuscripts, tapestry, and monumental effigies, in which there is often perplexing indistinctness. Now, painting comes to our aid; and the portraits by Holbein are the best illustrations of the costume of the two succeeding reigns. The male costume of the wealthier classes in the reign of Henry VII. consisted of a fine shirt of long lawn, embroidered with silk round the collar and wristbands. The sleeves of the doublet were slashed at the elbow, as in the reign of Edward IV.; or they were in two or more pieces, fastened at the shoulders and elbows with laces or points, through which the shirt protruded. The doublet was laced over a stomacher and petticoat, the male costume thus resembling that of the females in name as well as form. The outer garment was a long coat or gown, with loose hanging sleeves, and a broad turn-over collar of velvet or fur. The long hose were differently coloured in the upper and lower portions, and in the former, slashed or puffed; the shoes were absurdly long and broad-toed, and high boots were worn for riding. In the head-coverings, there was great variety. The hoods were abandoned to official habits, and instead were worn broad felt hats or caps, and bonnets of velvet or fur profusely decked with ostrich feathers; or the large plumed cap was slung at the back, and a smaller cap of velvet or gold net worn on the head. The knave of our playing-cards has a cap peculiar to this period.

In these distracted times, colours were worn distinctive of political party. Thus, the family colours of the House of Lancaster were white and red; those of York, purple and blue; and those

of Tudor, white and green. Buttons also bore partisan figures or emblems.

The female costume of the reign of Henry VII. is distinguished by the square cut of the bodice in the neck, and embroidered and jewelled stomachers, belts, and girdles hanging in front nearly to the feet; the sleeves were large and full, and when confined at the wrist resembled 'the bishops' sleeves' imitated in England, from the French, some years since. These sleeves were slashed, divided, and joined like those of the men. The head-dresses were close caps and cauls, from beneath which the hair hung down to the waist; and several kinds of capuchons were worn. In the dress of the humbler classes we find mentioned a 'furred flocket and gray russet rocket,' 'kirtle bristow red,' 'blanket hose,' 'Lincoln green,' &c.

At the close of this century the mourning habits had become so sumptuous as to be limited by law; the principal article being a barb or veil, used at funerals, which was tied on above the chin, by duchesses and countesses, and lower by all other ranks.

Throughout the above period, the principal material of the clothing of the middle classes must have been abundant; for, in the reign of Edward III. our woollen manufacture almost rivalled that of the Flemings, and our exports to the continent were very large; there appears, however, to have been little or no linen made at this period in England.

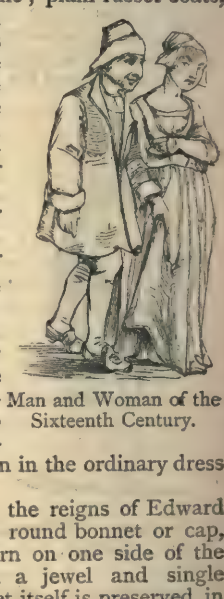
Sixteenth Century.

In the sixteenth century the upper part of the long hose began to be worn loose, or slashed with pieces of different colours let in, and the arms and shoulders of the doublet or jacket were fashioned in a similar style. Boots were also worn loose on the leg, with the upper part falling down; hence the origin of the *buskin*. Ruffs or ruffles, collars, and velvet bonnets with feathers, came likewise into use, as may be seen from the paintings of Henry VIII. Hall the chronicler describes several of Henry's superb dresses, and among them a *frocke*, or coat of velvet, embroidered all over with gold of damask, the sleeves and breast cut and lined with cloth of gold, and tied together 'with great buttons of diamonds, rubies, and orient pearls.' The cloaks and mantles were of corresponding magnificence. The shirts were pinched or plaited, and embroidered with gold, silver, or silk. The term *hose* continued to be applied to the entire vestment from the waist to the feet, throughout this century: the material is more distinctly stated, for Henry wore knit silk as well as cloth hose; the precise period of the separation of the hose into breeches and stockings is not so clear as the derivation of the latter term from the '*stockying* of hose;' 'that is, adding the lower part that covered the legs and feet to that which was fastened by points to the doublet,' and was called the *stocks*. The shoes and buskins were of the German fashion, very broad at the toes, and of velvet and satin, slashed and puffed. The hats, caps, and bonnets were of almost endless forms and colours.

Henry passed sumptuary laws, directing that cloth of gold and tissue should be used only for dukes and marquises, and that purple should be kept for the royal family. Earls might use embroidery, and commoners of distinction silks and velvets; and it was even thought necessary to restrict the commonalty and serving-men to cloth of a certain price, and lambs' fur, and to forbid them wearing any ornaments, or even buttons, save the badge of their lord or master. The king, likewise, forbade his courtiers' wearing long hair, according to the general fashion, and made them poll their heads, which led to the introduction of the peruke, afterwards written *periwig*, and more shortly *wig*. The masques, or plays in masquerade, in Henry's reign, were very splendid; and in the ladies' dresses worn at one of them are mentioned 'demy sleeves, naked down from the elbows,' which M. Planché considers to have been the first appearance of bare arms since the time of the ancient Britons. Gloves were not unknown, for Henry left a pair to one of the executors of his will. They were sometimes finely perfumed, and brought from Spain and Italy as presents. In this and the preceding reign the head-dresses assumed a different character, having long lappets or ear-pieces hanging down below the shoulders, and when made of velvet studded with pearls, jewels, and gold, they were truly superb. Three-cornered caps of minever were also worn throughout the reign; and the close-fitting cap reaching to the ears, and known as 'Mary Queen of Scots' cap,' was first worn about this period. The ladies' hunting dress differed but little from the riding-habit of the present day; across it was usually slung, from the right shoulder to the left side, a horn resembling a bugle.

In this reign, *pins* were first brought from France, and used by Catharine Howard, before which time the different parts of the dress were kept together by ribbons and loopholes, laces with points and tags, clasps, hooks-and-eyes, and skewers of brass, silver, and gold; but the poorer classes used the natural thorn for the above purpose.

The dress of the middle ranks in this reign may be seen in prints of the time; plain russet coats, and white kersey sloppes, or breeches, with stockings of the same piece, were the ordinary suit; and the London apprentices wore blue cloaks in summer, and gowns of the same colour in winter, as badges of servitude; for this appears to have been the age of domestic distinctions—the relics of the feudalism of the middle ages. The women wore sheep, russet, or long woollen gowns, worsted kirtles (hereafter called *petticoats*), and white caps and aprons; and milk-white under-linen came into general wear. The engraving shews a man and woman in the ordinary dress of this period.


Man and Woman of the Sixteenth Century.

The principal novelty of the reigns of Edward VI. and Mary was the flat round bonnet or cap, of plain velvet or cloth, worn on one side of the head, and decorated with a jewel and single ostrich feather. The bonnet itself is preserved in the caps worn at the present day by the boys of

Christ's Hospital; and their blue coat and yellow stockings are such as were worn by the London apprentices at the date of the foundation of the hospital by the youthful Edward. The gown of the wealthier classes was furred with sables in front and round the broad sleeves. Philip, on his marriage with Mary, brought into England a richer style of dress for the men, particularly the close ruff; the doublet, which fitted exactly under the chin, and the short Spanish cloak—all of which remained for a considerable time in fashion. The preposterously large stocks, or trunk-hose. continued to be worn, but the broad-toed shoes were discarded. The armour continued nearly the same as in the preceding reign. To female costume the chief addition was the *farthingale*, an immense hooped petticoat, introduced from Spain under Queen Mary. The entire dress was worn very close, so as to conceal the person as much as possible.

Queen Elizabeth's fondness for dress is well known; she is stated to have left three thousand different habits in her wardrobe. This great number is explained by the royal affectation of wearing by turns the costume of all the nations of Europe, which may be traced to the use of foreign materials made up by foreigners. Bohun tells us that 'when she appeared in public she was richly adorned with the most valuable clothes, set off again with much gold and jewels of inestimable value; and on such occasions she even wore high shoes, that she might seem taller than indeed she was. The first day of the parliament she would appear in a robe embroidered with pearls, and upon her head she had a small crown. She was dressed in white silk, bordered with pearls of the size of beans, and over it a mantle of black silk, shot with silver threads. Her train was very long. Instead of a chain, she had an oblong collar of gold and jewels.'

But the glory of the Elizabethan era of female costume, as well as its most remarkable characteristic in the sixteenth century, was the *ruff* of plaited linen or cambric, which now became superb, and rose from the front of the shoulders behind the head nearly to its full height; from the bosom descended a huge stomacher, on each side of which projected the immense farthingale. In this characteristic costume Elizabeth went to St Paul's Cathedral to return thanks for the defeat of the Spanish Armada; though, besides the magnificent ruff, the queen wore a mantle with a large wing-like collar, her hair intertwined with pearls, large pendent jewels on the neck, and a superb lattice-work of pearls over the entire dress.

The ruff must, however, be further noticed: no sooner had its material been changed from holland to lawn or cambric, than a difficulty arose as to starching or stiffening it, instead of the clumsy mode of supporting it by poking-sticks of ivory, wood, or gilt metal. At length the art of starching was brought from Flanders, and taught in London for a fee of four or five pounds. The fashion next lay in the colour of the starch, of which there were five varieties.

Stockings, which we find mentioned as foreign rarities in the wardrobe accounts of Henry VIII. and Edward VI. became common of home manufacture in the reign of Elizabeth. In the third year a pair of black knit silk stockings, made in England, was presented to her majesty, who was so pleased with the article, that she would never after wear cloth hose. This resolution has been attributed to Elizabeth's desire to encourage English manufactures by her own example, and may be taken as some set-off to her extreme fondness for foreign materials and fashions of dress. Soon after this, a City apprentice, having borrowed a pair of knit worsted stockings brought from Mantua, made a pair like them, which he presented to the Earl of Pembroke; and these are the first worsted stockings known to have been knit in England. Mary Queen of Scots, at her execution, wore stockings of blue worsted, clocked and topped with silver, and under them another pair of white; and the stockings of this time generally consisted of silk, jarnsey, worsted, crewel, fine yarn, thread, or cloth, of all colours, and with clocks, open seams, &c. The invention of the stocking-frame by Lee at Calverton, near Nottingham, in 1599, must have brought stockings into general use: he or his brother is said to have worked for Queen Elizabeth; but he was driven by the jealousy of the other stocking-manufacturers into France, where he died of a broken heart—an end by no means uncommon in the lives of inventors.

The garters of this age were very costly, sometimes of gold or silver, and four or five pounds a pair; they are presumed to have been worn by ladies since the time of Edward II.; but they must not be confounded with the leg-bandages of an earlier date. The ladies wore 'cocked shoes, prisnets, pantofles, or slippers,' which raised them two inches or more from the ground: these were made of black, white, green, or yellow velvet, or Spanish and English leather, embroidered with gold, silver, or silk, and shaped after the right and left foot, like the Anglo-Saxon sandal. The Elizabethan head-dresses were French hoods, hats, caps, kerchiefs, cauls of net-wire, and lattice caps—the last, as well as an ermine bonnet, being forbidden by law to all but 'gentlewomen born, having arms.' In Elizabeth's jewel-box is a long list of wigs, or rather head-dresses, among which are cauls of hair set with seed-pearl and gold buttons. The hair was curled, frizzled, and crisped, and under-propped with pins and wires into the most fantastic forms. The finger-rings, earrings, bracelets, and other jewellery, were very splendid: velvet masks and pocket looking-glasses were carried by fashionables, with fans of ostrich feathers set in gold, silver, or ivory handles—the last introduced from Italy, and used by both sexes.

The male costume in Elizabeth's reign was the large trunk hose, long-waisted doublet, short cloak, hat, band, and feather, shoes with roses, and the large ruff; but the great breeches, 'stuffed with hair like woolsacks,' after the separation of the hose into this garment and stockings, appear to have been worn throughout the reign: they were made of silk, velvet, satin, and damask. The doublets were still more costly, and quilted and stuffed, 'slashed, jagged, pinched, and laced;' and over these were worn coats and jerkins in as many varieties as there are days in the year. The cloaks were of the Spanish, French, and Dutch cuts, of cloth, silk, velvet, and taffeta of all colours, trimmed with gold, silver, and silk lace and glass bugles, inside and outside equally superb. The stockings, shoes, slippers, and ruffs resembled those of the ladies.

Hats now began to supersede the bonnets of a former era. Those of beaver were exceedingly expensive, and they were for the most part made of felted wool, dyed. The most remarkable thing about these hats was their numerous shapes: some were steeple-crowned; others were flat and broad, like the battlements of a house; and others with round crowns, and bands of all colours, and ornamented with huge feathers and brooches, clasps, and jewels of great value.

In taking leave of the British costume of the sixteenth century, we may observe that its splendour was almost entirely borrowed from France, 'that country which has since given laws in dress to nearly all Europe.'

Seventeenth Century.

Under James I. the male costume was somewhat more decidedly Spanish, as respects the slashing and ornamenting of the doublet and breeches. Late in the reign, however, the jackets or doublets were shortened, and the breeches reduced in size, and fastened in large bows at the knees; the well-stockinged leg was admired, and the hat worn low in the crown, and with broad brim, as seen in portraits of the date 1619. Beards and whiskers had become almost universal in the reign of Elizabeth; but in that of James, the former was sometimes worn trimmed to a point, hanging down at the division of the ruff.

In the female costume there was little change. The huge farthingale continued to be worn by the nobility; a strong passion for foreign lace was introduced; pearls were the favourite jewels; and the ruff maintained its sway, so as to be anathematised from the pulpit; and the fancies of female costume were glanced at in a sermon preached before the king at Whitehall in 1607-8, as 'her French, her Spanish, and her foolish fashions; her plumes, her fannes, and a silken vizard, with a ruff like a sail, yea, a ruff like a *rainbow*, with a feather in her cap like a flag in her top, to tell which way the wind will blow.'

The dress worn in the reign of Charles I. is unrivalled for picturesqueness and elegant taste. At this we shall not be surprised, if we recollect that it was copied from the habit of Spain, the most becoming of all European costumes. Early in this reign, however, the motley fashion of the time of James I. prevailed; and the Savoy neck-chain, the ruff and cuffs of Flanders, the Naples hat with the Roman hat-band and Florentine agate, the Milan sword, and the cloak of Geneva set with Brabant buttons, gloves from Madrid, &c. were the characteristics of the beau of 1629. The ruff had almost universally given place to the falling band; and collars of rich point-lace, large and hanging down on the shoulders, held by a cord and tassel at the neck, and now called *Vandyke*, from its being the most striking part of the dress in which Vandyke at that time painted portraits.

The principal habits were vests and cloaks of velvet, or silk damask, short trousered breeches terminating in stuffed rolls, and fringes and points, and very rich boots, with large projecting lace tops. A dress of Charles is thus described: A falling band, green doublet (from the armpits to the shoulders wide and loose), zigzag turned-up ruffles, long green breeches (like a Dutchman's), tied below the knee with yellow ribbons, red stockings, green shoe-roses, and a short red cloak lined with blue, with a star on the shoulder; the king sometimes wore a large cravat, and at other times a long falling band with tassels. The dress of the gay courtiers or cavaliers consisted of a doublet of velvet, silk, or satin, with large loose sleeves, slashed and embroidered; Vandyke collar and band, and short embroidered cloak, worn on one shoulder; the long breeches, fringed and pointed, met the ruffled tops of the boots; the embroidered sword-belt was worn over the right shoulder, and in it was hung a Spanish rapier; and in the flapping beaver hat was worn a plume of feathers confined by a jewel. A buff coat or jerkin was often worn, as a better defence than the doublet, which is sometimes covered. The engraving represents a citizen of this period more plainly attired.

The female costume of this period was rather elegant than splendid. Gowns with close bodies and tight sleeves were worn, though the farthingale was retained, with a gorget ruff standing up about the neck like a fan. French hoods were still worn, though with little distinction as to rank. The hair was worn in small curls, and the hoods, of all colours, fastened under the chin with curious effect. Ear-rings, necklaces, and bracelets were much worn; but the Puritans forbade the females to wear lace, jewels, or even braided hair; and they retained the close hood and high-crowned hat.

Towards the close of the reign of Charles I. the cumbrous farthingale disappeared, with the yellow starched ruff and band. These tasteless fashions having disappeared, the female dress became very elegant, with its rich full skirt and sleeves, and falling collar edged with rich lace, and the hair worn in graceful ringlets; but these vanities were condemned by the Puritan party.

With the Restoration of Charles II. came certain tasteless innovations upon the elegant Vandyke costume of the time of Charles I. which were

Citizen in the time of Charles I.

Citizen's wife in the time of Charles II.

the first resemblance to the coats and waistcoats of the present day. Thus our most picturesque attire lasted little more than a quarter of a century. Its decline was gradual; its chivalric character soon degenerated into grotesqueness, which in its turn changed to stark meanness. Early in the reign of Charles II. the doublet was much shortened, and worn open in front, where, and at the

waistband, the rich shirt was shewn; and the loose sleeves and breeches were decked with ribbons and points, and from the knee-bands hung long lace ruffles. At the wrists, too, ruffles were worn; but the lace collar was shorn of its points, designated to this day Vandyke. The cloak was retained upon the left shoulder, and the high-crowned and plumed hat remained for a short time; but the crown of the hat was soon lowered.

The petticoat breeches were another absurdity; although ornamented with ribbons at the sides, the lining strangely appeared below the breeches, and was tied at the knees; to match which, the sleeves of the doublet only reached to the elbows, and from under them bulged the ruffled sleeves of the shirt, both being ornamented with ribbons. Meanwhile the skirt of the doublet had been lengthened from above the waist nearly to the knees, and had buttons and button-holes in its entire length, thus becoming a *coat*, and so named in an inventory of 1679; wherein also are the items of *waistcoat*, *breeches*, *pantaloons*, *drawers*, and *trousers*, being the earliest mention of these articles. Stockings of various kinds were common; and 'the lower ends of stockings' are understood as socks. Instead of the lace collar was worn the long square-ended cravat of the same material, from Brussels and Flanders.

The female costume, as if to compensate for the tasteless additions to that of the men, retained much of its elegance in Charles's reign; indeed from this time 'the stronger sex' appear to have left the art of dress to the ladies. The portraits of the beauties of the court of Charles II. in Windsor Castle and Hampton Court Palace, are familiar illustrations, in which we see only a pearl necklace upon the bosom, and the hair falling in luxuriant ringlets from beneath a string of pearls. The gowns are of the richest satin, low in the bosom, and have long trains, so that the wearers could not 'stir to the next room without a page or two to hold them up.' The preceding engraving represents a citizen's wife performing this office herself.

Passing to the reigns of James II. and William III. we find few noticeable novelties in costume. The coats were often of velvet, without collars, with large hanging sleeves, and button-holes of gold embroidery. The petticoat breeches were exchanged for the close-fitting garments tied below the knee, and therefore called *knee-breeches;* the broad-brimmed hats were turned up on two sides, and edged with feathers or ribbons; the fashion lay in the rich long lace cravat and embroidered waistcoat; the band was now narrowed, so as to resemble that worn at the present time by clergymen. The periwig was worn still longer than hitherto, hanging down in front, or flowing upon the shoulders, though the colour was altered from black to suit the complexion; and combing these wigs was a piece of foppishness, for which purpose a comb was carried, whence the origin of our present pocket-comb: and at court, in the walks of Kensington, the Mall of St James's, or the boxes of the theatre, the beaux turned their wig-curls over their fingers whilst in conversation: the effect of these wigs flowing over the cuirass will be seen in the portrait of the great Duke of Marlborough.

The female costume was unchanged in the reign of James II.; but it became less luxuriant and more formal in the time of William and Mary, in accordance with Dutch taste. The waists were much lengthened with velvet stomachers, covered with jewels, so as to conceal the bosom, hitherto unsparingly exposed; the sleeve was made tight, and trimmed with lace lappets or ruffles, and long gloves were worn, so as entirely to cover the arm; but the skirts were worn long, full, and flounced; the hair, instead of flowing in ringlets, was gathered up, and strained over a toupee of silk or cotton-wool, carried up so high as to be called a tower, covered with a lace scarf or veil that hung in front below the bosom; but this head-dress gradually shrunk into a caul with two lappets, known as a 'mob.' False locks and curls, set on wires to make them stand out, were also worn. Before the Revolution, the citizens' wives dressed with becoming plainness, and gentlewomen wore serge-gowns, which, after 1688, were rejected by chambermaids.

Eighteenth Century.

In the early part of the eighteenth century, the costume of the English gentry was greatly affected by that introduced into general usage in France by Louis XIV. About the reign of Queen Anne, the new French fashions had been embraced by courtiers, physicians, and other professional persons in England, also the higher order of gentry; and in the following reigns of George I. and II. they became universal.

This dress of the old English gentleman, as it afterwards came to be called, consisted at first, during Queen Anne's reign, of a periwig in formal curls, partly contained in a silk bag on the shoulder; a small cocked-hat, full-bottomed coat, short breeches, blue or scarlet stockings drawn over the knee, and square-toed shoes, with small buckles and high red heels. And this formal costume, relieved only by lace cuffs, ruffles, and neckcloth, and gold or silver clocks in the stockings, remained unmodified through three-quarters of the century. The engraving shews a gentleman of the year 1750, and reminds us that the snuff-box, first carried in the reign of James II., continued indispensable for the 'fine gentleman.' The origin of the cocked-hat is easily explained. The wide flaps or broad brims of the hats in use being found to be inconvenient, they were looped up with a cord and button. At first this was done according to fancy, but latterly there were distinct fashions in cocking the hats. Cocked-hats, richly trimmed with gold-lace and ostrich feathers, occur in Hogarth's pictures, which indeed will furnish a better idea of the entire costume from 1727 to 1760 than many pages of description; and the portraits of Sir Joshua Reynolds will supply the dress of the next forty years.

The fashions of wigs were as various as those of hats. A peruke and a plaited and tied tail were called a Ramillies, from the famous battle of that name. The tie-wig became the fashion, from the celebrated Lord Bolingbroke going to court with his wig tied up, upon which Queen Mary observed that he would 'soon come to court in his night-cap'—a royal rebuke which established a fashion. In 1764, wigs went out of wear, and the wig-makers of London petitioned George III. to compel gentlemen to wear wigs by law, for the benefit of their trade! In the present day, formal wigs are almost confined to the

heads of prelates and barristers. Wigs are, however, much worn, from the greater prevalence of baldness than formerly; but their perfection now consists in bearing so close a resemblance to the natural or living hair as to avoid detection.

Towards the middle of the reign of George III. the male dress took the form of the court suit worn at the present day; the breeches having, from the year 1760, been worn over the knees, fastened by buckles or strings. The coats of the eighteenth century were of velvet, silk, or satin,

Lady in the time of George II.

Gentleman of 1750.

as well as broadcloth, and their colours very fanciful. Hogarth's favourite colour was sky-blue; Reynolds's, deep crimson and violet; and Goldsmith rejoiced in plum-colour. About 1790, cloth became the general wear; the waistcoat being of the costlier materials, and embroidered, and sometimes the breeches. Buckles were worn at the knees and in the shoes till the close of the last century; and the large square plaited buckle was the *ton* until 1791, when shoe-strings became general; though the Prince of Wales and his household endeavoured, by wearing buckles, to retain the fashion.

The female costume of the eighteenth century was as formal and tasteless as that of the men. The most odious piece of attire introduced in the early part of the century was the large whalebone petticoat, which degenerated into the hooped petticoat, and made a lady to appear as if standing in an inverted tub. In the reigns of George I. and II. loose gowns, called *sacques*, and hooded silk cloaks, were worn, and a very small muff, such as have been lately revived. This costume is shewn in the above portrait of a lady of George II.'s time. Ornamental aprons were also worn, as at the present day, with the watch, necklace, and the fan, which was sometimes from twelve to eighteen inches in length, and beautifully made.

Nineteenth Century.

The formalities of the eighteenth century received a terrible blow at the French Revolution; and in the ten years from 1790 to 1800 a more complete change was effected in dress by the spontaneous action of the people, than had taken place at any previous period in a century. The change began in France, partly to mark a contempt for old court usages, and partly in imitation of certain classes of persons in England, whose costume the French mistook for that of the nation generally. This new French dress was introduced by the party who were styled the Sans Culottes. It consisted of a round hat, a short coat, a light waistcoat, and pantaloons; a handkerchief was tied loosely round the neck, with the ends long and hanging down, and shewing the shirt-collar above; the hair was cut short, without powder, *à la Titus*, and the shoes were tied with strings.

The comparatively simple form of dress of the Sans Culottes found many admirers in England, and soon became common among young men; the change from antique fashions was also greatly helped by the imposition of a tax on the use of hair-powder, which was henceforth generally abandoned. Pantaloons, which fitted closely to the leg, remained in very common use by those persons who had adopted them till about the year 1814, when the wearing of trousers, already introduced into the army, became fashionable. It is proper, however, to mention that trousers had, for the previous fifteen or twenty years, been used by boys, and were perhaps from them adopted by the army. Previous to the French Revolution, the dress of boys was almost the same as that of men. Although trousers were generally worn after 1815, many elderly persons still held out in knee-breeches against all innovations, and till the present day an aged gentleman may occasionally be seen clinging to this eighteenth century piece of dress. The general use of white neckcloths continued, notwithstanding the introduction of the standing collar, till the reign of George IV. when this monarch's taste for wearing a black-silk kerchief or stock, and also the use of black stocks in the army, caused a remarkably quick abandonment of white neckcloths, and the adoption of black instead. The year 1825, or thereabouts, was the era of this signal improvement in costume.

While these leading changes were effecting, other alterations of a less conspicuous nature were from time to time taking place. The disbanding of the army after the peace of 1815 led to various transformations besides those we have mentioned. While pantaloons were the fashionable dress, it became customary to wear Hessian boots; these, which had originated among the Hessian troops, were without tops, and were worn with small silk tassels dangling from a cut in front; being drawn over the lower part of the pantaloons, they had a neat appearance, but the keeping of them clean formed a torment that prevented their universal use. When trousers were introduced from the practice of the army, the use of Wellington boots to go beneath them also became common.

Referring to the era of 1815 to 1825 as that in which trousers, Wellington boots, and black neckcloths or stocks came into vogue, we may place the introduction of the surtout in the same period of history. From the time when the collarless and broad-skirted coat had disappeared about the commencement of the century, the fashion of coats had changed in various ways till the above-named era, when the loose frock-coat or surtout was added to the list of garments. We remember seeing French military officers, when in undress, wearing frock-coats as early as 1811; it is probable, therefore, that the modern surtout is only a variety of the loose military greatcoat brought from the continent by the British army; however

it originated, it may be allowed to be one of the greatest improvements in the style of dress which has yet occurred in the nineteenth century.

We have adverted to the absurd article of women's attire, the *farthingale*, as introduced from Spain under Queen Mary, and to its reappearance in the eighteenth century. We now come to the development of this fashion about the middle of the present century; which began with *crinoline* (Fr. from L. *crinis*, hair), a fabric made of horse-hair, first in the form of the inelegant 'bustle' in the upper part of the skirt, then the whole petticoat. Instead of the hair-fabric, some used, for economy, cotton, thickly corded and starched. At length, about 1856, people were startled by the question: 'Have you heard that Miss So-and-so actually wears a hoop?' and it became apparent that the fashion of Queen Anne's time had returned upon us, only that the structure was somewhat lighter and more pliant; being usually composed of a series of horizontal small steel hoops, held together either by vertical bands, or by being sewed into a kind of petticoat. Unlike former times of hoops and farthingales, the fashion descended even to maid-servants, so that where the dining-room was small, table-maids have been known to give warning because they could not clear the space between the table and the fire; and the newspapers were continually announcing 'Accident from Crinoline,' or 'Lady burned to Death from Crinoline.' The *Spectator* dealt out much cutting, though playful raillery on the hoops of his day, but apparently with little effect; and equally unavailing were the satires of *Punch* and other caricaturists of the nineteenth century against the hideous fashion of crinoline. The hoops were sometimes made with a circumference of four, and even five yards. At last, after indignation and ridicule had for years assailed the monstrosity in vain, and when people had given over speaking about it, the inflation began about 1866, without any apparent cause, to collapse; and rushing to the opposite extreme, ladies might be seen walking about as slim as if merely wrapt in a morning-gown or bathing-dress. The sole relic of this kind of expansion now to be seen is a

Chignon.

structure of lappets, called a pannier, projecting behind, immediately below the waist.

But women, it would seem, can never rest contented without adding, in one direction or another, to their proper dimensions; for the former crinoline was soon supplanted by great cushions or pads of frizzled hair, applied chiefly to the back of the head, and covered over by the natural hair, or by artificial tresses. Such a cushion was known as a *chignon* (Fr. the neck or neck-hair). This fashion was not new, but was carried to greater extravagance than ever before, the head being sometimes rendered three times its natural size.

But it is vain to expect that female attire will ever be reasonable and in good taste; and, on the whole, that of the present day is probably as chaste and becoming as it ever has been, or as we are ever likely to see it; from which commendation, however, we must except the ever-changing and never very classic-looking bonnet. The male attire of our time is plain, and for the most part in good taste, except the 'dress-coat' and hat, both of which are as unnatural in shape as they are uncomfortable to wear. And yet, though convinced of an occasional absurdity in the matter of costume, it is the wiser course rather in so far to follow than attempt to lead in an altogether different direction. 'A man,' says Feltham, and he says wisely, 'ought, in his clothes, to conform something to those that he converses with, to the custom of the nation, and the fashion that is decent and general, to the occasion and to his own condition; for that is best that best suits with one's calling and the rank we live in. And seeing that all men are not Œdipuses, to read the riddle of another man's inside, and that most men judge by appearances, it behoves a man to barter for a good esteem, even from his clothes and outside. We guess the goodness of the pasture by the mantle we see it wears,' and 'the apparel oft proclaims the man.'

PROVINCIAL PECULIARITIES.

The *Welsh*, as a relic of an ancient Celtic people, possess remarkably few external traits of their original. They have, like the Irish, become Anglicised in costume, and we should in vain search amongst them for the *breacan*, or checkered clothing, of their Celtic ancestry. The most remarkable part of the Welsh costume is the hat worn by the women. All females in parts of the country not modernised wear round black hats, like those of men; and this fashion is supported to a small extent by ladies of the higher rank. This use of the hat is not Celtic; the fashion is derived from England, and is only two or three centuries old.

The *Irish* at an early period wore the same Celtic fashion of attire as was preserved till recent times in the Scottish Highlands; but, as in Wales, everything of the kind disappeared as the country became Anglicised. A primitive species of attire, including coloured mantles, kirtles, and other fanciful garments, remained in use till the sixteenth century, when laws were passed by Henry VIII. enjoining the use of caps, cloaks, coats, doublets, and hose of English cut, but of Irish or any other materials. The general dress in Ireland, at the present day, rarely varies from that in England. There are, however, some interesting peculiarities of costume amongst the peasantry of the southern and western counties.

The costume of the Lowland Scotch has generally resembled that of the English in all its

changes and vicissitudes. Anciently, the dress of the Scotch, both those of the Highlands and Lowlands, was distinguished by party-colours, woven in checks, according to taste or ancient usage. By the Celtic race in the Highlands, this species of variegating cloth with colours was called *Breacan*, which signifies spotted; and by the Teutonic population of the Lowlands it received the name of *Tartan*, a word whose origin has defied the researches of etymologists. To the present day, cloths checked in various colours are worn by the Kalmucks and other tribes in the north of Europe. Tartan for clothing disappeared in the Lowlands of Scotland in the course of the seventeenth century; but even as late as the beginning of the eighteenth century, party-coloured plaids were pretty generally worn; and young women were in the habit of using a 'tartan screen'—that is, a small plaid of variegated colours. The tartan screen, which was worn in the fashion of a covering for the head and shoulders, so as to combine in some measure the properties of a modern bonnet and shawl, was formed of costly materials; the ladies of the higher classes employing silk, and those of inferior station fine worsted, the colours in each case being remarkably brilliant. Being often employed with a degree of real or affected modesty to conceal a part of the features, it may be said to have performed the office of a veil to Scottish maidens; and hence its appellation of *screen*. Perhaps the use of this species of coif was a consequence of a point of etiquette, which rendered it indecorous for young unmarried women to wear any regular garment on the head.

While tartan disappeared from the Lowlands, except in the screens of the women and the plaids of the shepherds, it continued to be in universal use in the Highlands, where it may be said to have been always associated with the manners of the people; and this leads us to say a few words respecting

Highland Costume.—Originally, the costume of the Highlanders resembled that of other Celtic tribes, and consisted of little else than a woollen garment of variegated colours, wrapped round the body and loins, with a portion hanging down to cover the upper part of the legs. In progress of time this rude fashion was superseded by a distinct piece of cloth forming a fillibeg or kilt, while another piece was thrown loosely as a mantle or plaid over the body and shoulders. In either case, the cloth was variegated in conformity with the prescribed *breacan*, or symbol of the clan; and hence the tartan was sometimes called *cath-dath*, or battle-colours, in token of forming a distinction of clans in the field of battle.

In 1747, with the view of breaking the spirit of the clans, a law was enacted proscribing the use of the Highland dress, including the tartan in all its varieties. The following is the provision in the act of parliament on the subject: 'That from and after the 1st day of August 1747, no man nor boy, within that part of Great Britain called Scotland, other than such as shall be employed as officers and soldiers in His Majesty's forces, shall, on any pretence whatever, wear or put on the clothes commonly called Highland clothes—that is to say, the plaid, filibeg or little kilt, trowse, shoulder-belts, or any part whatsoever of what peculiarly belongs to the Highland garb; and that no tartan or party-coloured plaid or stuff shall be used for greatcoats or for upper-coats; every person offending, being convicted by the oath of one or more credible witnesses before any court of justiciary, "shall suffer imprisonment, without bail, during the space of six months;" and being convicted for a second offence, shall be transported to any of His Majesty's plantations beyond seas, there to remain the space of seven years.' This contemptible law was repealed in the year 1782; but before that time the tartan and 'the garb of old Gaul' had been generally abandoned, except among Highland regiments, and it is chiefly copies from their attire that have guided modern attempts at reviving the costume.

The bonnet has for ages been a part of the Highland costume, as it was formerly also of the Lowlanders, and of the English, previous to the introduction of felt hats. The English gave up bonnets sooner than the Scotch; and ultimately the cry that 'the blue bonnets are over the Border,' was equivalent to saying that a party of Scotch marauders had entered England on one of their usual hostile excursions. The Highlanders, with whom the bonnet has remained longest as a part of ordinary dress, have adopted very many shapes and modes of ornamenting their headgear. The heavy plume of black feathers used in the army is quite modern, and in exceedingly bad taste, besides being totally unconformable to the idea of a primitive and light costume. The true bonnet of the Highlands is small, either round or peaked in front, dark-blue or gray in colour, and without any tartan or checkering. In fancy dress, however, the bonnet is somewhat larger, and occasionally has a band of tartan. Highland chiefs were distinguished by three pinion feathers of the native eagle stuck in the bonnet; and gentlemen were entitled to wear a single feather. It was customary also for the members of each clan to wear in the bonnet a peculiar badge formed of some native shrub. Authorities differ as to the precise shrubs worn for this purpose. The Buchanans used a sprig of bilberry; the Camerons, crowberry; the Campbells, fir-club-moss; the Forbeses, broom; Frasers, yew; &c.

The full dress of Highland chiefs and gentlemen has always been liberally ornamented with sword, baldrick, dirk, skean-dhu (worn in the stocking), large brooches, buckles, shot-pouch, and purse. The purse or sporan is a most important part of the costume; it is formed of the skin of a wild animal with the hair on, and tied to the waist by a band, hangs down in front, so as to fall easily upon the lap, and not incommode the legs in walking. It is usually ornamented with silver tags and tassels, and a flap covering the mouth of the purse is sometimes decorated with the vizard of a fox.

After a period of indifference to the preservation of the Highland dress, a revival of the national tone of feeling respecting it has been for some time apparent. At the same time, it is employed only as a fancy costume; and in the Highlands, the ordinary dress of the English is in common use.

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*** The Figures in the columns indicate the pages of the Text in which the particular term or subject is fully explained.

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